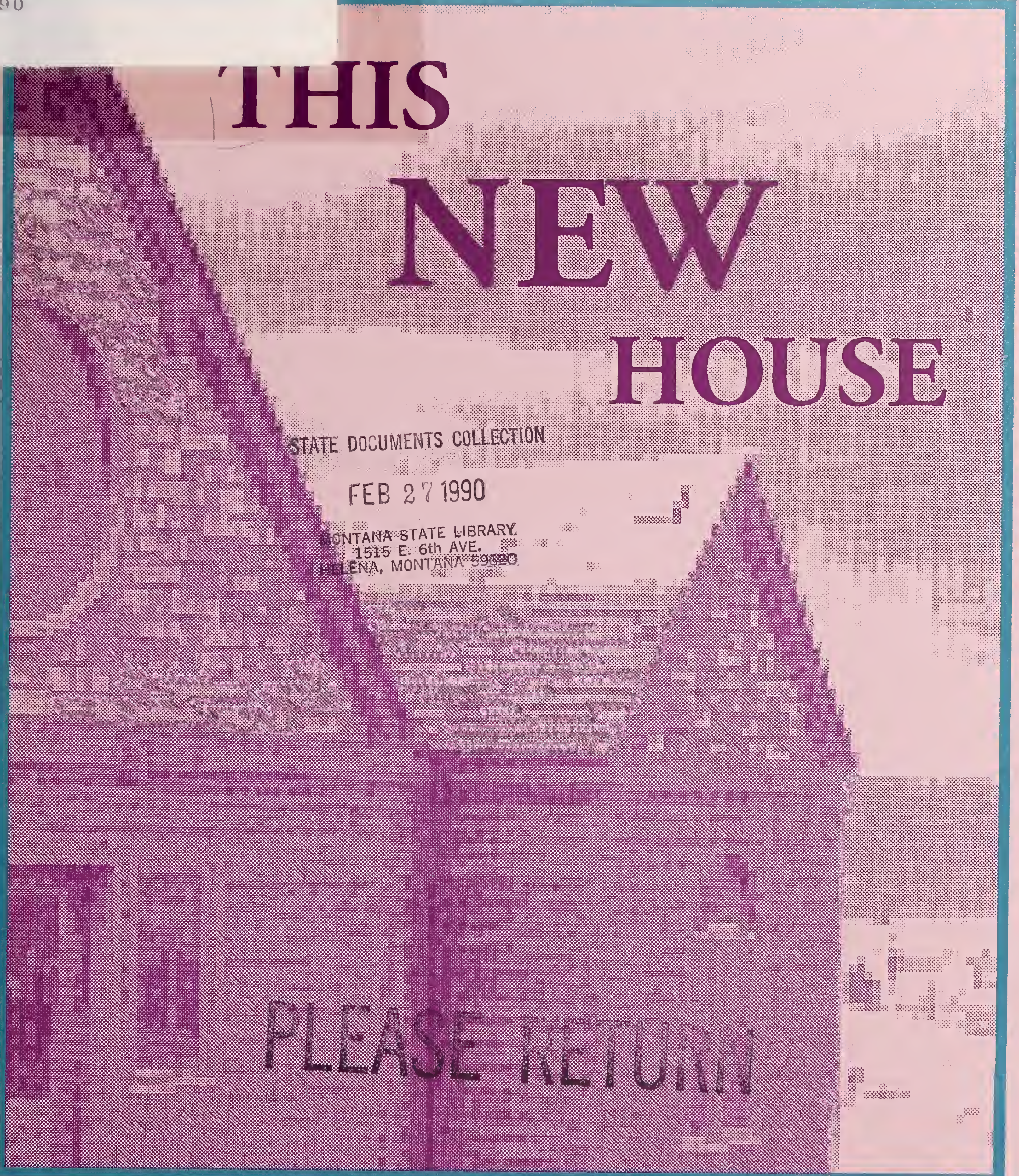
# THIS NEW HOUSE





DNRC

## Crafting houses for comfort and savings in Montana

# THIS NEW HOUSE



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Natural Resources and Conservation
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# Publications Staff


| | |
|---|---|
| **Project Direction:** | Brian Green, Mike McCourt |
| **Writing:** | Patricia Kelley |
| **Editing:** | Daniel Vichorek |
| **Technical Review:** | Brian Green, Tom Livers, Jim Maunder, Neil Marsh, Mike McCourt, Marc Scow |
| **Graphic Design:** | Barbara Lien |

# Thinking of Building a New House?

This book is for everyone planning to build a house in Montana. It explains how energy-efficient design, construction, and operation can make a house more comfortable and cut energy use by half or more. Although this book is not a manual of house construction, it should enable prospective house builders to ask the right questions and make the right decisions regarding energy-saving measures.

It makes sense to include energy-efficient features in a house as it is built, rather than renovating later. Key features such as double wall construction in outer walls, insulation of foundation and floor, and proper air sealing are much cheaper and easier to build into a new house than to add to an existing one.

*It makes sense to include energy-efficient features in a house as it is built, rather than renovating later.*

Comfort alone is a good reason to build an energy-efficient house. Energy-efficient houses are draft-free, resulting in uniform temperatures throughout rooms, even next to outside walls and windows. Rooms also are generally quieter, because thicker walls and more insulation shield the house from outside noise.

Moreover, lower space heating requirements over the life of the house save money and insulate the homeowner against increases in the cost of energy. A sizeable portion of the space heat for many of these houses comes from solar energy that is admitted through south-facing windows. Usable heat also is supplied by the water heater, stove, refrigerator, other appliances, light bulbs, and people.

## Calculating Costs and Benefits

Are the benefits of increased comfort and better use of space heat worth the extra materials and effort put into an energy-efficient house? To gauge costs and benefits of energy-saving construction, start with "basic" construction.

Consider a basic house as one built to standards established by the U.S. Department of Housing and Urban Development (HUD) as applied in Montana. Such a house is required to have insulation levels of R30 to R38 in ceilings (depending on the ceiling type), R19 in frame walls, R19 in crawl space floors, R11 in walls of an occupied basement (none required in unoccupied basements), R2 double-glazed windows, and R5.3 doors. HUD houses are not required to have most windows facing south.

### Upgrading

The energy efficiency typical of a HUD house can be improved through increased insulation, reduced air leakage, and better insulated windows oriented to the south. Two levels of upgraded house construction will be used to compare

building costs and energy savings: one built to Model Conservation Standards (see related article on this page), and one to a superinsulated level. The table on page 3 shows how the building components differ from HUD standards. The costs shown include the labor, framing, additional insulation, and other materials used to build or install the component, but exclude design costs and builders' overhead and profit. Costs of components exceeding HUD standards were calculated from the cost of these components in houses built from 1984 through 1986 as part of programs sponsored by the Bonneville Power Administration. They are median costs for Montana and will vary for other houses depending on local variations in the price of building materials and labor.

The following table illustrates component extra costs for the two levels of upgraded construction. The example is based on a 32 x 40 one-story house with 640-square-foot partial basement, for a total of 1,920 square feet of heated area. The extra cost for the MCS house is $3,084 or about $1.61 a square foot; for the superinsulated house the extra cost is $4,547 or about $2.36 a square foot. Adding 15 percent for builder's overhead and profit (typical for Montana) the housing costs may increase to about $3,547 for MCS and $5,229 for superinsulated.

## MODEL CONSERVATION STANDARDS

Model Conservation Standards (MCS) were developed by the Northwest Power Planning Council for new, electrically heated houses and commercial buildings. To conform to the standards, buildings must be constructed so their electric heating budget meets a certain level of energy efficiency. Although this level can be met in a variety of ways, the basic way is through higher levels of insulation. As defined by Bonneville Power Administration for Montana, the recommended minimum MCS insulation levels are R49 ceilings, R27 walls, R30 under floors over a crawl space, R19 on basement walls, and double-glazed windows with low-E film. MCS no longer requires special heat recovery ventilation but does require adequate mechanical ventilation, such as bath and kitchen exhaust fans, and strategically located fresh-air vents.

### COST ABOVE HUD STANDARDS

| COMPONENT | SQUARE FEET OF COMPONENTS | MCS INCREMENTAL COST ABOVE HUD REQUIREMENT | SQUARE FEET OF COMPONENTS | SUPERINSULATED INCREMENTAL COST ABOVE HUD REQUIREMENT |
|---|---|---|---|---|
| Ceiling insulation | 1288 | @ $0.40 = $515 | 1288 | @ $0.50 = $644 |
| Wall insulation | 922 | @ 0.59 = 544 | 922 | @ 0.80 = 738 |
| Basement walls | 576 | @ 0.20 = 115 | 576 | @ 0.20 = 115 |
| Floor insulation over crawl space | 640 | @ 0.34 = 218 | 640 | @ 0.34 = 218 |
| Slab insulation | 208 | @ 0.48 = 99 | 644 | @ 0.48 = 307 |
| Air-vapor barrier | 1932 | @ 0.18 = 348 | 1932 | @ 0.18 = 348 |
| Doors (2) | | 0 | | 0 |
| Windows | 230 | @ 2.15 = 495 | 230 | @ 2.15 = 495 |
| Mechanical Ventilation | | 750 | | 1682 |
| Builder's Overhead and Profit | | @ 15% = 463 | | @ 15% = 682 |
| Total | | $3547 | | $5229 |

| Component | HUD standards | MCS standards and incremental cost above HUD | Superinsulated levels and incremental cost above HUD |
|---|---|---|---|
| Ceiling | Standard Truss | Advanced Truss | Advanced Truss |
| R-Value | R30 Cathedral/ R38 Attic | R38 Cathedral/ R49 Attic | R60 |
| Extra Cost | | $0.40/sq. ft. for attic | $0.50/sq. ft. |
| Walls | 2x6 | 2x6 strapped 2x8 2x6 w/foam board | Double wall |
| R-Value | R19 | R27 | R38-R42 |
| Extra Cost | | $0.59/sq. ft. | $0.80/sq. ft. |
| Basement (finished) | Walls framed with batt insulation | Walls framed with batt insulation | Walls framed with batt insulation |
| R-Value | R11 | R19 | R19 |
| Extra Cost | | $0.20 sq. ft. | $0.20 sq. ft. |
| Slab | | Perimeter insulation around outer 2 feet of slab | Full underslab insulation |
| R-Value | | R10 | R10 |
| Extra Cost | | $0.48/sq. ft. | $0.48/sq. ft. |
| Crawl Space | Floor/crawl space walls insulated | Floor/crawl space walls insulated | Floor/crawl space walls insulated |
| R-Value | R19 | R30 | R30 |
| Extra Cost | | $0.34/sq. ft. | $0.34/sq. ft. |
| Air-Vapor Barrier | Non-continuous polyethylene in walls none in ceiling | Non-continuous polyethylene or ADA in ceiling and walls | Continuous polyethylene or ADA in ceiling and walls |
| Extra Cost | | Poly=$0.18/sq. ft. | Poly=$0.18/sq. ft |
| Windows | Double-glazed | Double-glazed with low-E | Double-glazed with low-E |
| R-Value | R2 | R3 | R3 |
| Extra Cost | | $2.15/sq. ft. | $2.15/sq. ft |
| Doors | Foam core | Foam core | Foam core |
| R-Value | R5.3 | R5.3 | R5.3 |
| Extra Cost | | | |
| Ventilation | 50 cfm bathroom fans, non-circulating range hood | Non-heat Recovery Mechanical Ventilation with fresh air ports | Heat Recovery Mechanical Ventilation |
| Extra Cost | | $750 | $1682 |

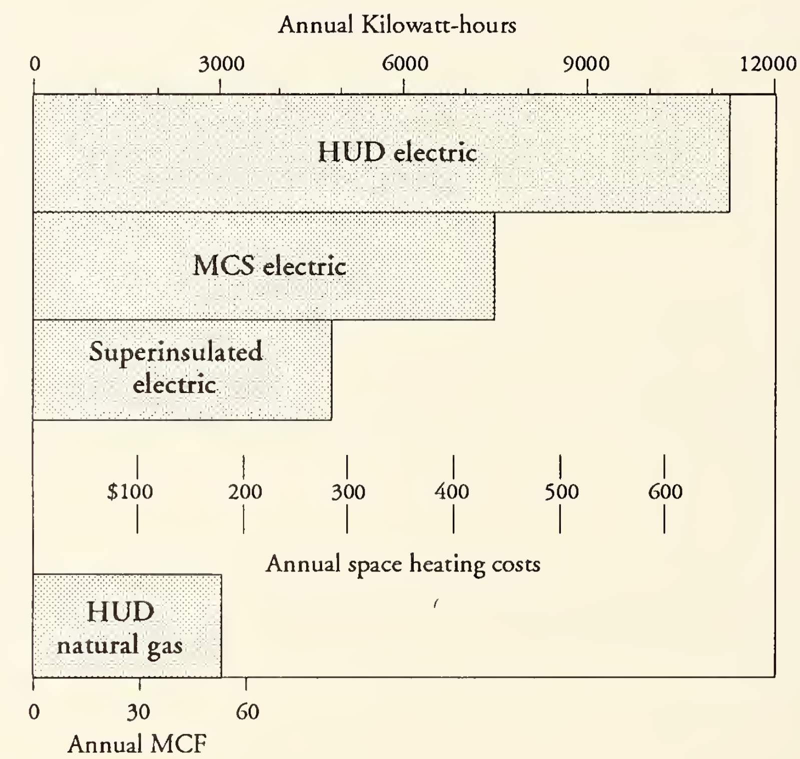
Note: Stated costs are median (midway between the highest and lowest costs observed) and are more representative than average or mean costs.

### Energy savings

So, does the energy saved justify the extra insulation and other items for each of the hypothetical house upgrades? Yes, for electrically heated houses. Consider the energy use for the hypothetical house constructed to HUD, MCS, and super-insulated levels. For each of the houses, the estimated energy use is based on three occupants, each using 15.6 gallons of hot water daily. It is assumed that appliance use contributes 550 kilowatt-hours (kWh) per month to internal heat. Cost of fuels is based on $3.50 for a thousand cubic feet (MCF) of natural gas, and 5 6/10 cents a kWh for electricity. One MCF provides 1,000,000 Btu. One kWh provides 3,413 Btu.

*So, does the energy saved justify the extra insulation and other items for each of the hypothetical house upgrades? Yes, for electrically heated houses.*

***Comparing Space Heating Costs and Fuel Usage for a Hypothetical 1,920-square-foot House***




When using natural gas, the HUD house requires 53.7 MCF a year or about $190 for space heat. The big savings come when electricity is used for heating. The HUD house uses 11,967 kWh annually at a cost of $670. Annual kWh usage for the MCS house drops to around 7,762 costing $435. The superinsulated house uses 5,053 kWh for an annual heating bill of about $283.

### Impact on monthly budget

The best way to analyze the benefit of the upgraded construction is by weighing monthly space heat savings against the monthly mortgage increase for the upgraded construction. The following calculations for the hypothetical 1932-square-foot house are based on a 30-year loan at 10.5 percent interest, with a 10 percent down payment. The mortgage amounts for MCS and superinsulated houses are reduced by the tax write-off for the interest on the increased mortgage amount.

When electricity is used for space heat, the lower monthly heating bill in the MCS and superinsulated houses almost offsets the increase in the mortgage

| | MCS | Superinsulated |
|---|---|---|
| Increase in monthly mortgage | $29 | $42 |
| Less tax write-off on interest | 6 | 9 |
| Net increase in mortgage | 23 | 33 |
| Less savings on space heat | 20 | 32 |
| **Net monthly mortgage increase for upgraded construction** | $3 | $1 |

payment for the upgraded construction. Once the additional construction costs are paid off, the savings in space heat costs are "gravy." Future increases in energy prices will make the payback even quicker. Considering that most houses are occupied for 70 years or more, the savings potential is sizeable.

Besides returning costs and providing a buffer against rising fuel prices, upgraded construction increases comfort by eliminating drafts and lowering the noise level. The payback in comfort begins immediately and continues for the life of the house.

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## Determining the best option

Fuel prices and climate determine how much extra can be spent for upgraded construction, insulation, and airtightness, while still keeping combined mortgage and heating costs low. The colder the climate and the greater the price of fuel, the greater the savings and the more that can be spent on insulation strategies.

People who heat with natural gas may find HUD insulation standards adequate, although they may want to upgrade basement wall insulation and add low-E windows for increased comfort and savings.

Most local utilities and several builders offer an energy analysis that predicts the annual space heat requirement based on the proposed design for a house. A computer program analyzes variables such as local climate, a house's size, design, site, and amount and orientation of glazing. The program can do "what if" projections that show how space heat needs will vary if insulation is added to walls, basement, ceiling, or floor, or if low-E windows or some other energy-saving measure is installed. The program also considers the number of occupants and their living patterns. Two adults gone during the day will certainly use less energy than a family with children who are home during the day, and running in and out.

It is up to the home buyer to compare the savings in space heat to the cost of the upgraded construction to achieve those savings. One method is to request two bids from each builder bidding the job—one for a basic HUD house, and one for the level of insulation the home buyers feel is best for their comfort and energy savings.

# Planning and Designing the Energy-saver House

The strategy for building an energy-efficient house begins with thoughtful planning that considers the building site, the possibilities for passive solar gain, and the overall design of the house.

## Choosing the Building Site

The best site plan takes advantage of natural features such as a south-facing slope. If the north side of a house can be sunk below ground surface on a south-facing slope, less surface area is exposed to the wintry blasts from the north, and the south side is still accessible to the warming rays and natural lighting from the low winter sun. A good view to the north needn't be sacrificed, however. Thoughtful window selection and placement can minimize the disadvantages of north windows.

Benefits of a well-sited house extend beyond reducing the need for auxiliary heat and light in the house. If the yard surrounding the house is well protected, entries are more comfortable to use, outdoor play spaces are usable on sunny winter days, and outdoor use areas such as patios can be comfortably used from spring through fall.

Vegetation and soil berms can be used to protect a house from the weather. A windbreak of closely spaced evergreens placed a distance of one to two house heights upwind will help protect the dwelling from wind. Shading the house with deciduous trees can substantially reduce summer roof and wall temperatures.

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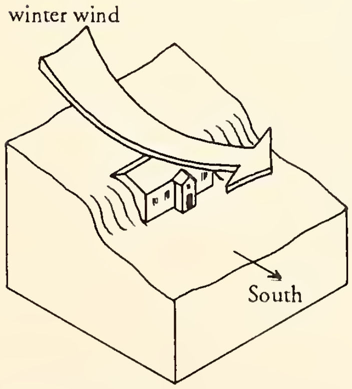
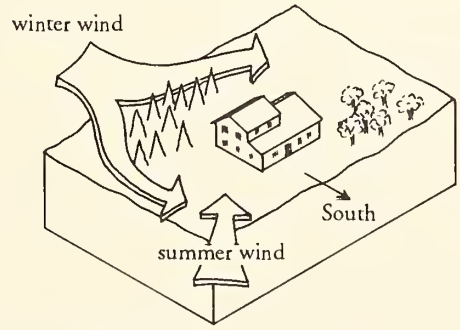
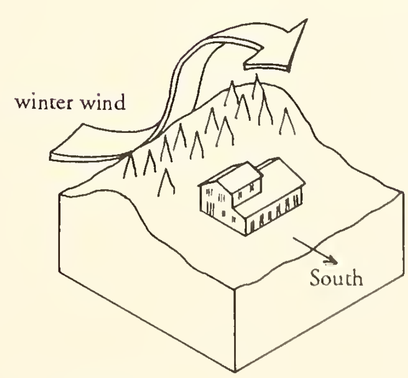



Earth Shelter




Landscaping




Soil Berm

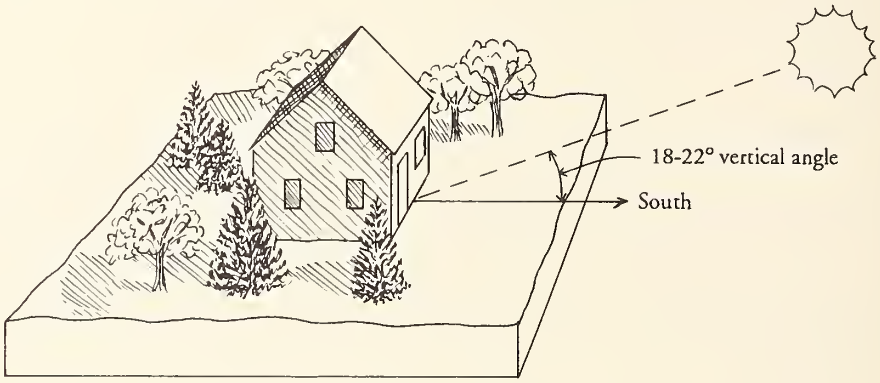
## Solar Considerations

### Orientation

A properly oriented and designed house can acquire a significant amount of its space heat from the sun. Sun entering through the windows heats up the interior surfaces and furnishings, which helps keep the space warm after sundown, reducing the time that the heating system must operate.

Placing the house on an east-west axis exposes the south side to maximum heat gain in the winter. In Montana, the long side of a house can face as much as 30 degrees east or west of true south (not magnetic compass south) and still receive over 90 percent of the available solar energy. Orienting south-facing windows to the east of true south means early warming of rooms in the winter. Orienting the windows west of true south results in afternoon warming, which usually is less desirable than morning warming. West-facing windows are subject to overheating all year long because the setting sun is low no matter what the season.

*For optimum heat collection, south windows must have full access to the sun on winter days without the interference of trees or buildings. The sun's angle determines the maximum height of trees or buildings on the south side of a house. On December 21 at noon, the sun's angle will be 18½ degrees above the horizon at Havre and increase as one moves south—to 22 degrees at West Yellowstone, for example.*




*Orientation*

No obstacles should be in the way of the low angle rays of the winter sun from about 9:00 a.m. to 3:00 p.m. when more than 90 percent of the usable winter solar radiation occurs. If the sun is blocked for even one hour, up to 20 percent of this energy will not be available.

### Windows

Space devoted to windows should equal 8 to 15 percent of the total floor area. Of the total glazing, 50 percent should be placed on southern exposures, 30 percent on the east and 20 percent on the west. North-facing windows usually should be minimized, but in some cases may be desirable for viewing or cross ventilation. South-facing windows with low-E glazing (see page 24) can have a net winter heat gain. This means that more heat is collected through the windows during the day than is lost at night. East- and west-facing windows usually lose more heat at night than they gain during winter days. North-facing windows have no heat gain and lose a great deal. Heat loss through windows can be eliminated or minimized by covering them with insulated window shades at night.

### Shading

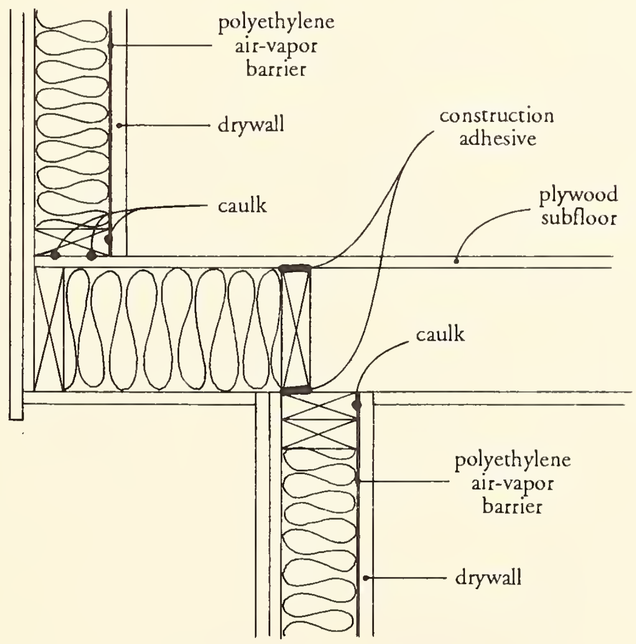
The installation of most glazing on the south can reduce the total space heating bill, but offers a potential for overheating unless adequate shading and ventilation are provided. An 18- to 24-inch roof overhang will shade south-facing

windows from late April to late September at most Montana latitudes. When the sun is lower in the sky, the window becomes less shaded so all available solar energy enters during the heaviest heating season—late October to late February. Where the length of the overhang is restricted such as on the gable ends of a house, an awning mounted just above a window will provide shade.

Although blinds or draperies stop the sun's rays from striking the interior, much of the heat is already in the building after passing through the glass. Exterior shades are more effective in preventing overheating. Shading can be augmented with deciduous trees or with window coverings. Thought should go into the selection and placement of deciduous trees, some of which can block up to 50 percent of the sun, even without their leaves.

## The Influence of Design

A compact shape and simple floor plan contribute to building convenience and construction savings. A streamlined house is much easier to make energy efficient than one with many levels, projections and corners. However, the dormers, cupolas, and cantilevers that create the interesting jogs and roof angles of a house needn't be eliminated if care is taken to ensure that the exposed areas are sealed and insulated.



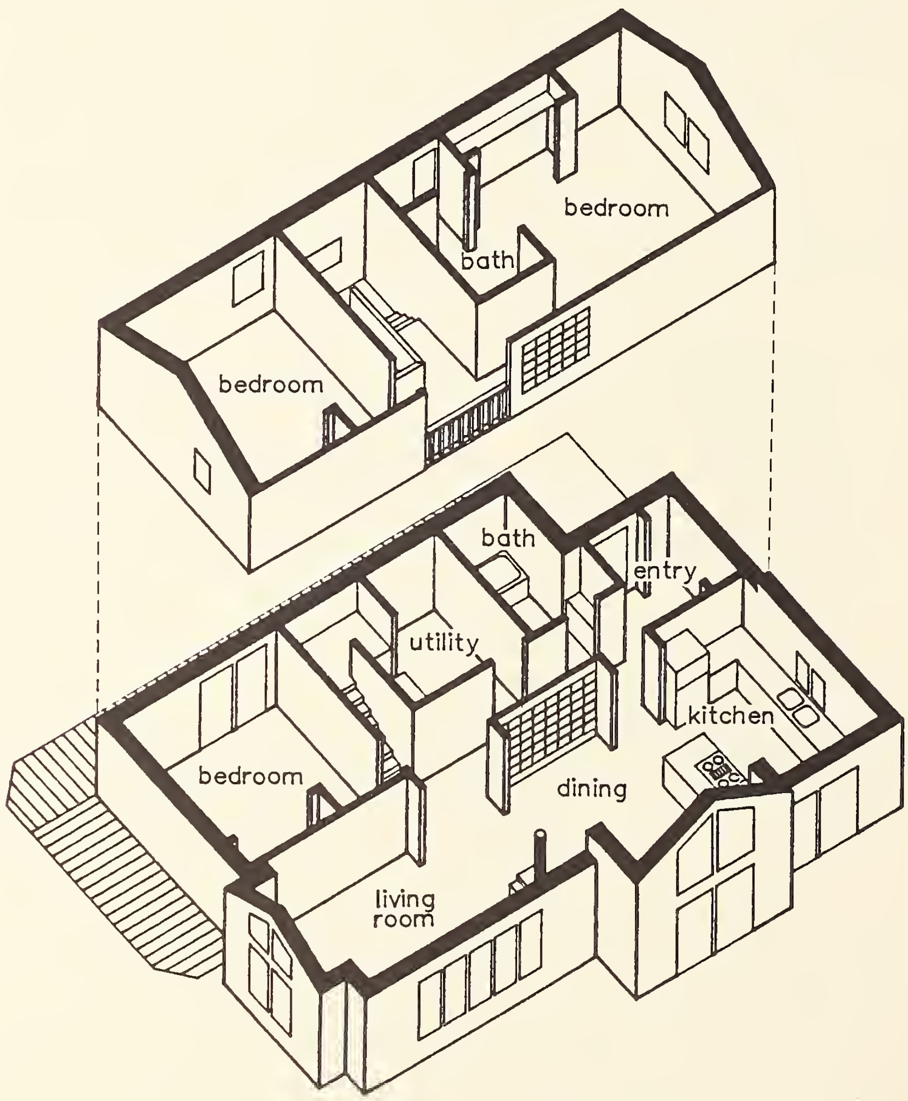

*Cantilever Treatment*

The design of energy-saving houses considers solar energy, natural light, and room relationships. Rooms used often by all family members, such as living or family rooms, should take advantage of natural light and solar heat. Placing these rooms on the south side enables the sun to warm the space during the day. Living areas that will be used primarily in the evening should be located in the southwest part of the house to take advantage of natural evening light. The working areas—utility, bathrooms, and garage—require plumbing, more artificial light, and lots of storage. These rooms require few if any windows and can be placed on the north side. Bedrooms placed on the east side allow for enjoyment of the early morning sun.

Many energy-saving plans have the living spaces open to one another so that passively heated air is free to move around the space. This usually works better than a house with many separate rooms that restrict movement of heated air to various areas. Houses with forced air heating, however, can use the furnace fan to move air.

Sunspaces should be designed with plenty of ventilation, shading, or thermal storage so they won't overheat.

Recessed or sheltered entries and those facing east or south will avoid letting in the worst winter weather. An airlock entry will also reduce drafts. Placing the garage on the northwest buffers the house from chill winter winds and can create a sheltered entryway or double as a vestibule.




*Room Placement*

# Trapping the Heat

## How Homes Lose Heat

Even poorly sited houses with little potential for passive solar gain can be energy efficient when the ceiling, walls, foundation, windows, and doors are thoroughly insulated and sealed. To understand the benefits of proper insulation and sealing, it is necessary to understand how heat is lost in a house. Heat moves from areas of higher temperature to areas of lower temperature. It moves by three methods: conduction, convection, and radiation.

Conduction refers to the movement of heat through a solid object. One example is the conduction of heat from a stove burner through an iron skillet. Another example is heat traveling from a house's warm interior through studs in the exterior wall to the outdoors.

Convection refers to the movement of heat through a fluid such as air or water. Wind blowing against a warm window and carrying heat away is an example of convective heat loss.

Radiation describes the transfer of heat from a warm object to a separate cooler object, but without affecting the temperature of the air. An example is a bonfire radiating heat to those standing nearby. Another example is radiation from warm household furnishings to cooler window panes.

These three methods of heat loss work in concert. For example, heat radiates from warmer furnishings to cooler outside walls or windows. From there it travels by conduction through the wall studs or window glass and frame to the exterior. Upon reaching the house's exterior, heat both radiates to cooler outside objects and dissipates through convection in the outside air. Convection heat also travels from a house's warm interior to the cooler outside through cracks where building components join and through openings where plumbing or electrical service enter the house.

## Insulation

Exterior walls, ceilings, and floors are kept warm by high levels of insulation, which reduce radiant heat loss and heat conduction through the building components. For an insulation system to be fully effective, it must be installed to eliminate gaps, thermal bridging, air intrusion into the insulation (common in attics), and moisture condensing in the wall cavity and wetting the insulation.

The amount of insulation required depends on the house's location and the price of fuel or electricity used in heating. The recommended insulation levels are

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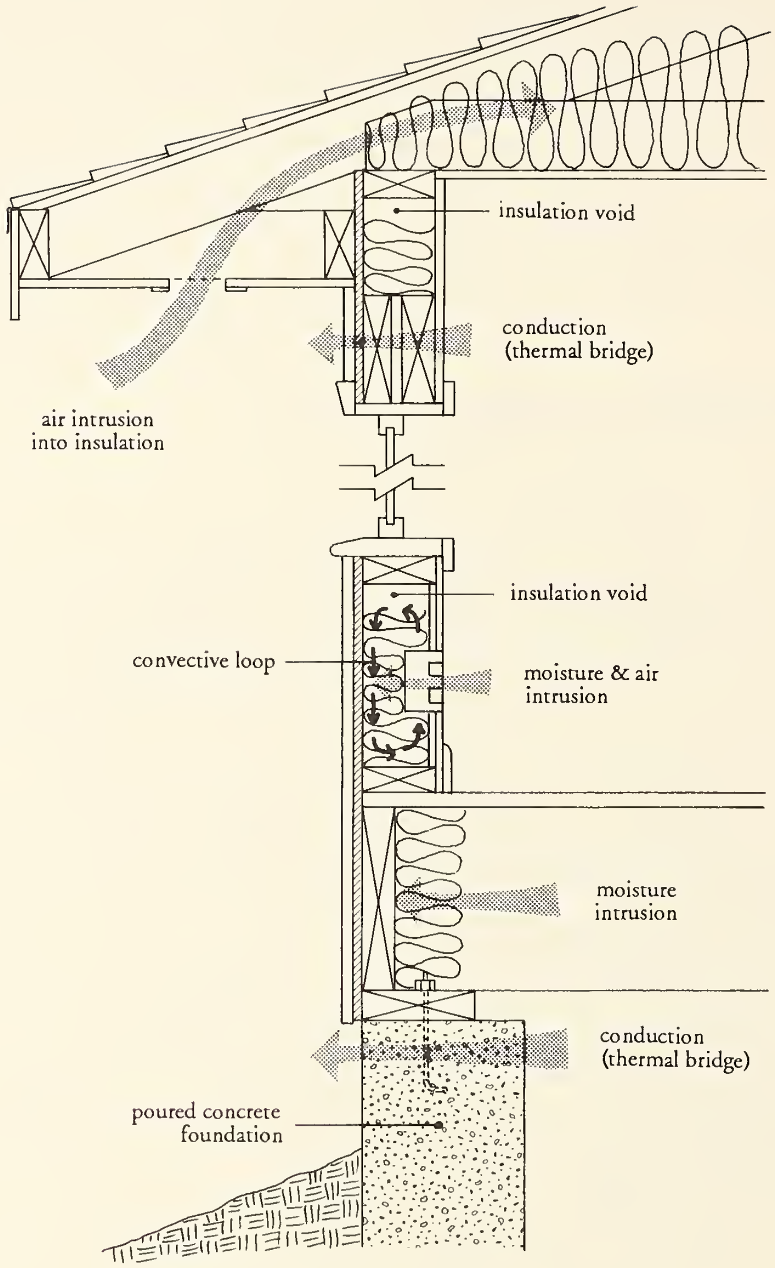



*Thermal Defects*

## INFRARED SCAN

A trained technician can use an infrared camera to "photograph" or scan the surface temperatures of a building. The infrared scan measures and displays the temperature difference of building components. From the display, the observer can quickly identify cooler surfaces. Cooler surfaces will include areas that have less insulation and more wood, such as studs, joists, and headers. Areas with missing or settled insulation also will be cooler, and often show up around the tops of stud cavities, recessed light fixtures, attic half-walls, and attic and crawl space hatchways. An infrared scan will also detect cracks in the building shell. To detect air leakage, an infrared scan is often used in conjunction with a blower door test (see related article on page 17). The blower door increases the amount of cold air brought in through openings, cooling the surrounding surfaces of even the smallest cracks, which are then located by the infrared scan.

**Recommended Insulation Levels for Houses**

| | Recommended R-Value: Gas Heat | Recommended R-Value: Electric Heat |
|---|---|---|
| Ceiling | 30 - 38 | 38 - 60 |
| Walls | 19 | 27 - 42 |
| Basement walls | 11 | 19 |
| Slab | 0 | 10 |
| Floors over unheated spaces | 19 | 30 |
| Doors | 5 | 5 |
| Windows | Double Pane | Low-E or Triple Pane |

shown in the table above. R-value refers to a material's ability to stop heat from passing through it; the higher the R-value, the better the insulation resists heat loss. ("Measuring Heat Flow" in the Appendix explains the basis for R-values.)

Most insulation is one of five types: blanket, loose fill, sprayed, foamed in place, or rigid. The R-values of a few of these insulation types are shown below.

| Insulation Type | R-Value Per Inch |
|---|---|
| Fiberglass batts | 3.2 |
| Fiberglass blown-in batts | 4.0 |
| Cellulose loose fill | 3.4 |
| Extruded polystyrene rigid foam | 5.0 |
| Polyurethane/polyisocyanurate: | |
| rigid board | 7.4 |
| foamed-in-place | 7.0 |

The recommended insulation levels can be achieved by using one or more types of insulation.

**Blanket insulation** (often called "batt") is suitable for application to vertical cavities (as in walls) or placed in ceilings or floors.

**Loose fill insulation** works well for horizontal surfaces such as ceilings where space is available. It is essential that loose fill materials made of wood or paper products be treated for fire resistance.

Loose fill also can be **wet-sprayed** with an adhesive to take form as blown-in-blankets or blown-in-batts (BIBS). Wet-spray insulation is applied under pressure from a "gun" to fill open cavities in walls or attics. This type of insulation can fill small spaces where batts may not fit.

**Foamed-in-place** urethane is injected to the desired thickness in open wall cavities or attics. This type of insulation fills small spaces and also acts as an air and vapor barrier. It has one of the highest R-values per inch.

Various types of **rigid** insulation are made from products such as polystyrene, fiberglass, urethane, and polyisocyanurate. They are more expensive than other types, but offer high R-values per inch. Rigid foam often is used on the outside of concrete or wood walls, and under concrete floor slabs.

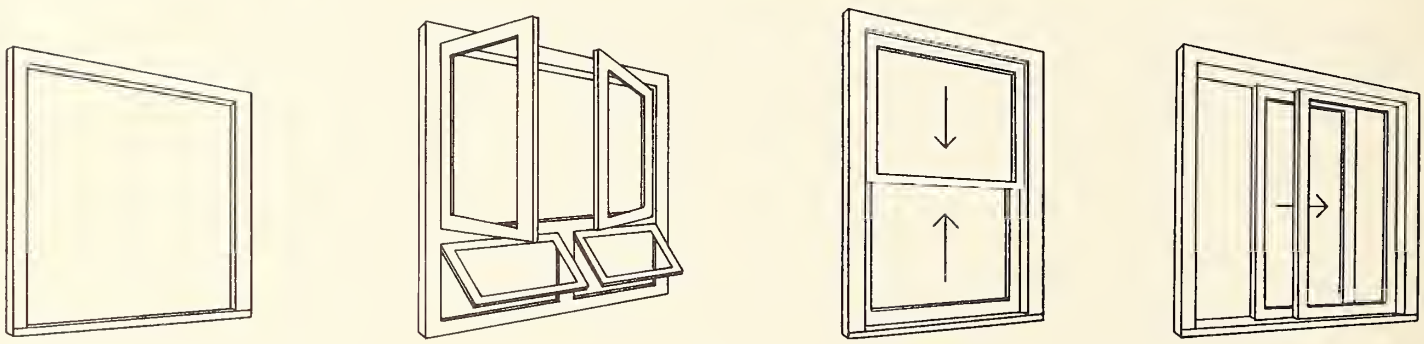
*Essentially, windows are poorly insulated holes in the walls of a house.*

## Windows

Although windows are desirable for passive solar heating, ventilation, natural lighting, and viewing, they also are significant heat losers. Essentially, they are poorly insulated holes in the walls of a house. Even the most efficient windows contribute to heat loss, dissipating about ten times more heat per square foot of glass than is lost by a square foot of wall area. Window design and placement thus become crucial to the energy use of a house.

Wood is the most common window frame material and is recommended for Montana climates. Wood requires less maintenance when covered with exterior cladding such as aluminum or vinyl.

Well insulated windows have fewer condensation problems and are more comfortable because the glass is warmer. When windows are cold or leaky, it doesn't take much humidity in the house to start water running down the panes.



1. Fixed    2. Casement and Awning    3. Double Hung    4. Sliding

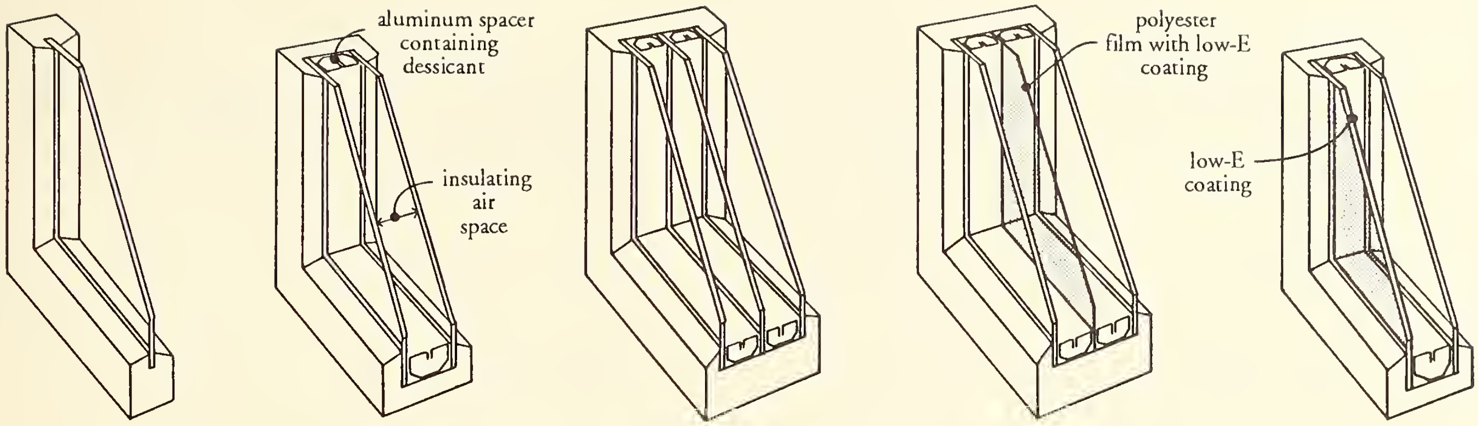
*Window Types in Order of Air-Tightness*

A main consideration among window designs is the amount of air leakage they allow around the edges. Generally, fixed windows are the tightest, followed in order of tightness by awnings and casements. Double-hung and slider windows have to be loose enough to allow the windows to slide, so they usually leak air at two to three times the rate of casements and awnings. Skylights must be well sealed and should have three glazing layers or low-E film to prevent excess heat loss.

Fixed windows should be used anywhere that an operable window isn't needed for ventilation or emergency escape. For large window areas, awning windows can

### LOW-E WINDOW COATING

Low-emissivity glass, called low-E, reduces heat loss through windows. A layer of metal oxides—copper, tin, or silver oxide is commonly used—is applied either to the air space side of the inner window pane in double glazing or to a thin layer of polyester film suspended between panes. The low-E layer reflects heat radiation before it can pass through the window. This effect keeps more heat energy inside during the winter and unwanted heat from entering during the summer. By reflecting heat into a room instead of letting it pass out, low-E film keeps the interior surface of the window warmer than double-paned windows without low-E. Low-E also filters out most ultraviolet rays, which can fade and deteriorate some draperies, upholstery, and carpeting.




*Glazing Types*

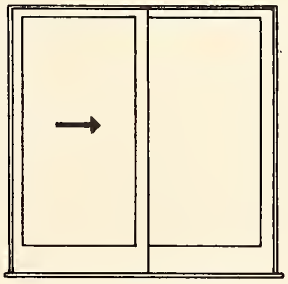
be installed under fixed units to provide the largest window area with the smallest operable area. Latching casements seal fairly tightly and also can be installed in combination with fixed windows. If the look of a double-hung window is desired, two awning windows of equal size can be stacked one above the other.

A variety of glazing systems have been designed to meet the recommended R3 insulation rating. Glazing refers to a layer of glass—a double-glazed window consists of two layers of glass separated by an air space. Whereas double-glazed windows have an R2 rating, a low emissivity (low-E) coating added to a double-glazed window increases the R-value to R3. Another means for achieving the higher insulation value is to install a clear polyester film suspended between panes in double glazing, without the weight of a third pane of glass. This film can also have a low-E coating applied to it to achieve an R4 rating. One of the newest window treatment methods is placing argon or krypton gas in the space between panes in multi-paned windows to achieve a better insulation value. Adding low-E coating to the gas-filled windows further increases the R-value. The panes should have at least a 1/2-inch wide air space between them. A 5/8- to 1-inch wide space will provide better insulation.

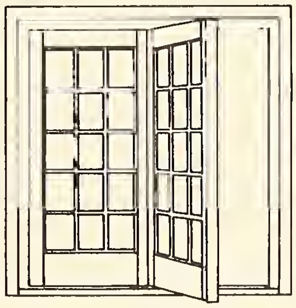
Manufacturer's air leakage ratings in cubic feet per minute (cfm) should also be compared. The lower the cfm rating, the tighter the window.

## Doors

An insulated metal (or fiberglass) door with a tight seal and a thermal break between the interior and exterior metal surfaces is optimum for solid exterior doors. Patio doors that are single- or double-swinging French (atrium) seal better than sliding glass patio units. Sliding glass doors can be thought of as big sliding windows. Like the slider windows, they have to be loose enough to slide and, thus, don't seal as tightly as the atrium style door.



*Sliding Glass Door*



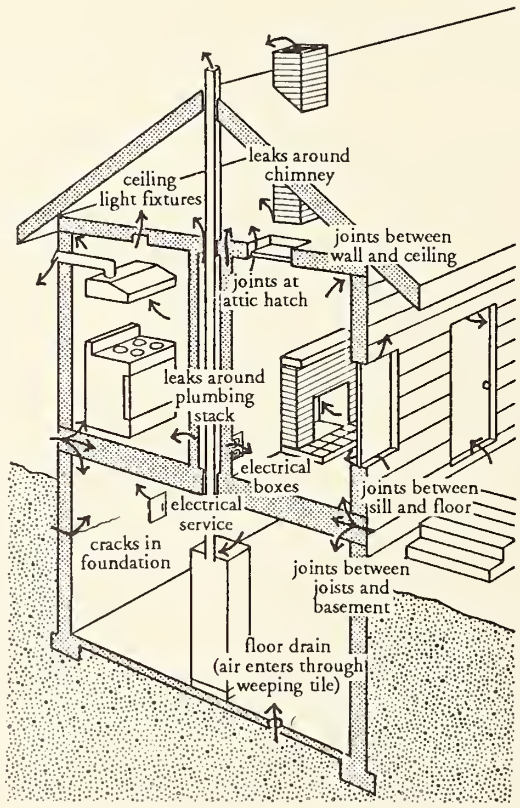
*Atrium Door*

## Controlling Air Leakage

While most people recognize the value of properly insulating a house, the importance of controlling air leakage is not as well understood. The air leakage in a conventionally built house is usually equivalent to the leakage that would result from a single hole about one foot square through an outer wall. A conventionally-built house leaks its entire volume of inside air to the outside about every four hours. About 15 to 20 percent of the total heating bill goes toward heating replacement air from outside.

A conventional house may leak air through exterior walls, basement, windows, doors, ceilings, chimneys, and furnace vents.

*The air leakage in a conventionally built house is usually equivalent to the leakage that would result from a single hole about one foot square through an outer wall.*



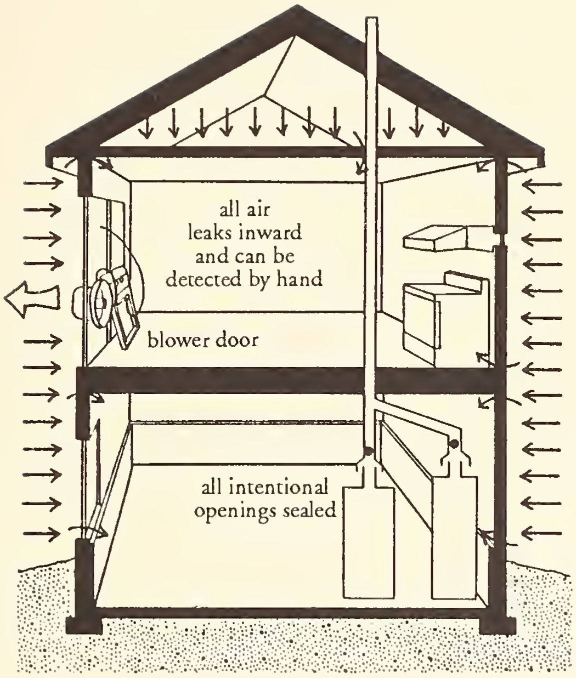

*Air Leakage Spots in a Conventional House*

### Air-vapor barrier

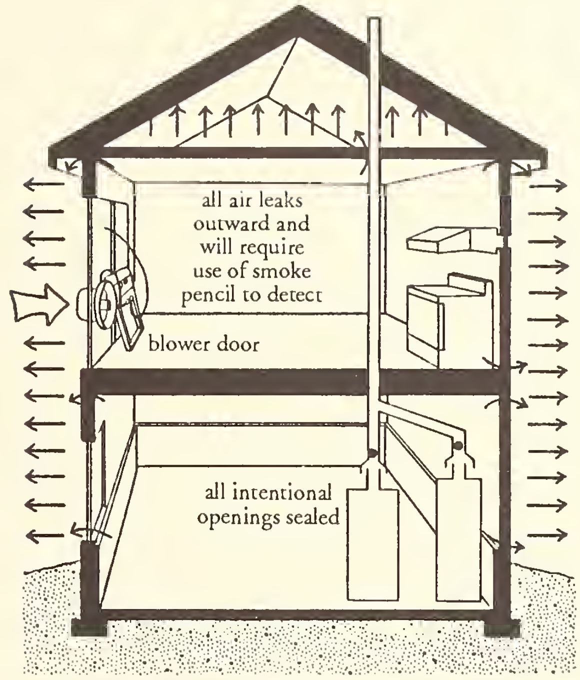
An air-vapor barrier prevents the movement of air and water vapor through exterior walls and ceiling. An air-vapor barrier can be a single component such as a plastic membrane, or a combination of materials such as drywall, gasketing, and vapor barrier paint, installed and joined to block movement of air and moisture. The latter strategy is known as the airtight drywall approach, abbreviated to ADA.

### Checking for air leaks

Although the barriers to air and vapor are hidden in the finished walls, ceiling, and floors of a house, it is possible to verify their performance. One method is the blower door test, which will tell if and where air leaks occur (see accompanying inset). These tests are available through specialized weatherization firms and blower door contractors. Evaluation of the house's airtightness readily reveals where improvements are needed.




*Depressurization Blower Door Test*




*Pressurization Blower Door Test*

## BLOWER DOOR TEST

A blower door test uses a variable speed fan mounted in a door or window opening to blow air into or draw air out of a house to simulate the effects of pressure differences that cause air infiltration or exfiltration. By artificially exaggerating the pressure difference that occurs naturally between the inside and outside of a house due to wind and temperature, the normal air change rate of the house can be estimated.

The test also aids in finding air leaks around windows, doors, baseboards, wall and ceiling joints, wall and floor joints, plumbing openings and electrical boxes. While the house is under pressure from the fan, a smokestick is used to track air leakage. The smoke drifts with the leaking air through cracks around windows, doors, baseboards, wall and ceiling joints, plumbing, and wiring penetrations.

# Building the Energy-efficient House

The key to an energy-efficient house is to keep heat in during the winter and out during the summer. This is achieved through a variety of construction methods and the use of appropriate materials and devices. Not all aspects of energy-efficient building are discussed in the following pages, but more information can be found in the books listed at the end of this publication.

## Foundations

Every building must have an adequate foundation to support it. In Montana, most foundations enclose a basement or crawl space, although some houses are built on a floor slab on the ground surface. Foundation materials include poured concrete, concrete block, and pressure-treated wood.

Proper drainage around a foundation is essential to keep moisture out of basements and crawl spaces, and to protect the foundation from frost heave. Drainage is especially critical in areas with a high water table, or in heavy soils such as clay or bentonite where the expansion of soil from water can crack the foundation.

*Proper drainage around a foundation is essential to keep moisture out of basements and crawl spaces, and to protect the foundation from frost heave.*

### Concrete basements

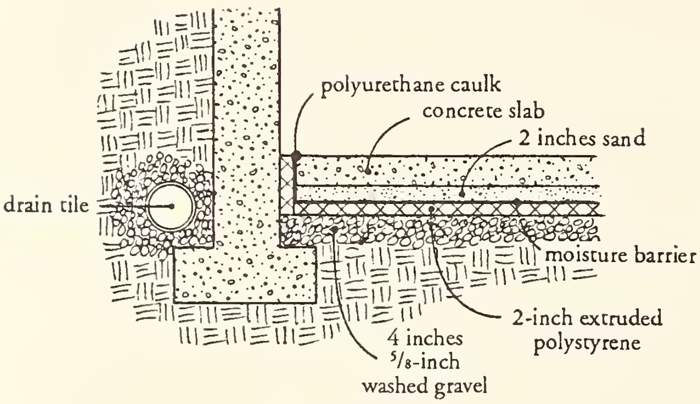
One-third of the total heat loss from a house can pass through uninsulated basement walls and slab. Although soil buffers a foundation from widely fluctuating outside air temperatures, it is not a good insulator. Saturated soil in contact with the foundation or slab significantly increases heat loss. This increased heat loss can result even if water is as much as 2 feet from the foundation or slab.

The amount of insulation and where it should be used on a foundation depends on local soil conditions, the method of construction, and cost limitations. Insulating the entire basement slab is probably not cost effective on energy savings alone, but it increases comfort by keeping the slab warmer in the winter. Because heat loss is greatest at the edges of a slab, insulation of the slab perimeter can be a good compromise. If in-floor radiant heating is to be used, it is critical that the entire slab be well insulated. Extruded polystyrene 1 to 2 inches thick is commonly used for slabs.

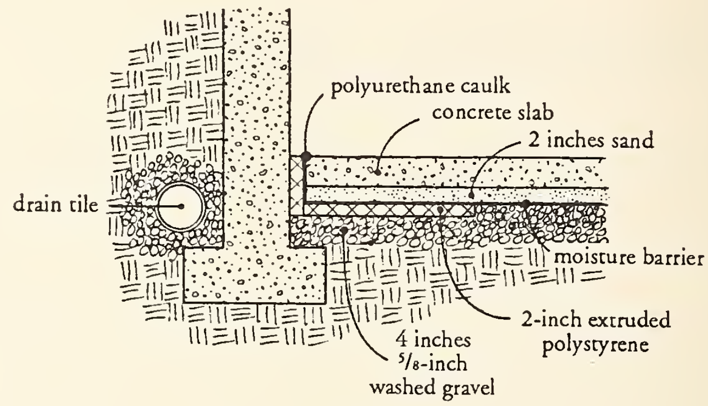
FROST HEAVE

When moist soil freezes, it expands. If this expansion occurs near a foundation, especially in non-porous soils such as clay or bentonite, it can push the soil upward, which can lift (heave) the foundation.

Both insulated and uninsulated slabs must have a moisture barrier of 6-mil polyethylene or a layer of crushed gravel (or both) to prevent ground moisture from wicking up through the slab. A damp slab conducts heat much more readily than a dry slab. When polyethylene is used, a sand fill placed between the slab and the polyethylene helps the concrete in the slab cure evenly and protects the polyethylene from damage during the concrete pour.



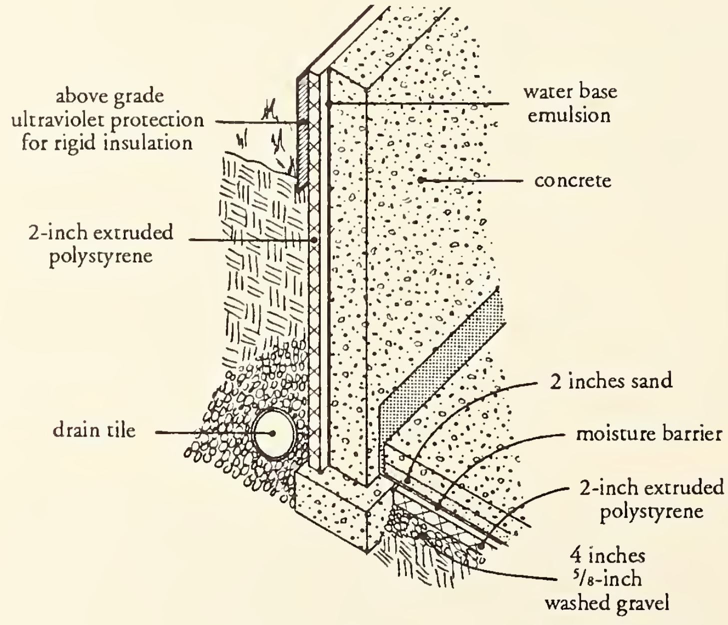

*Full Underslab Insulation*



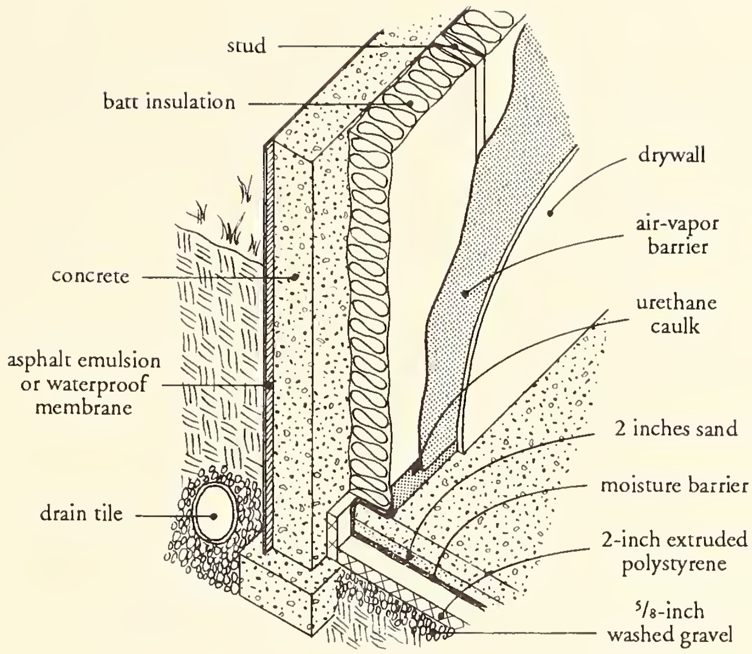

*Slab Perimeter Insulation*

For Montana locations with poorly drained soils (such as clay), insulation should be applied to the exterior of basement walls. Exterior insulation helps prevent freezing and frost heave of the soil under the footings. Exterior insulation on the rim joist minimizes loss of heat through the joist. Use of exterior insulation also allows the concrete to store heat without losing it to the outside. Exterior insulation doesn't consume any interior floor space.

Most basement walls have been insulated on the inside and this practice is likely to continue. Interior insulation can be done inexpensively and easily by the homeowner. The stud cavities provide room for wiring and plumbing.




*Insulation on Exterior Basement Walls*

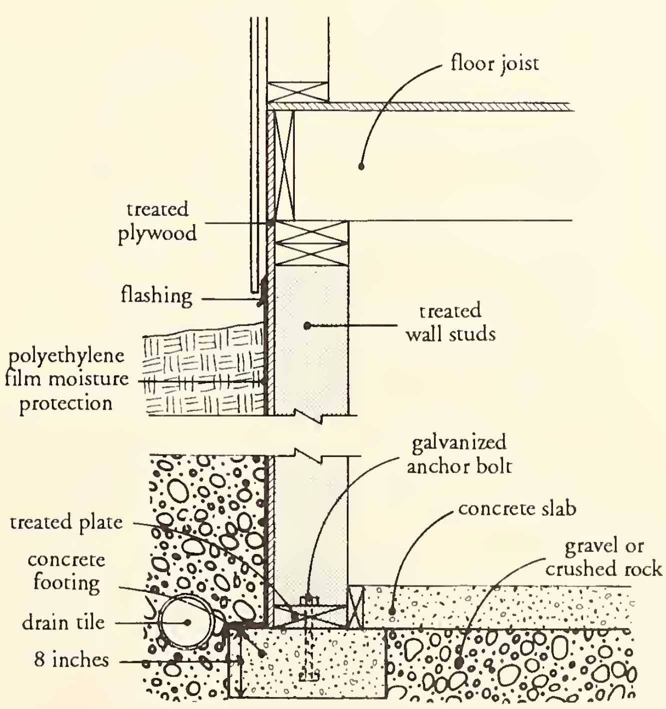



*Insulation on Interior Basement Wall*

## Permanent wood foundations (PWF)

Basement foundations made entirely of pressure-treated wood are becoming popular because they are easy to insulate and finish. However, they must be designed by a qualified engineer and constructed by competent builders who understand the importance of proper base preparation, handling techniques for pressure-treated wood, the use of correct fasteners, drainage installation, backfilling techniques, and sealing requirements.

The footings in a pressure treated wood foundation can be either a compacted gravel pad or a conventional concrete footing. The floor of a wood foundation can be either treated wood or a concrete slab.




*Typical Permanent Wood Foundation*

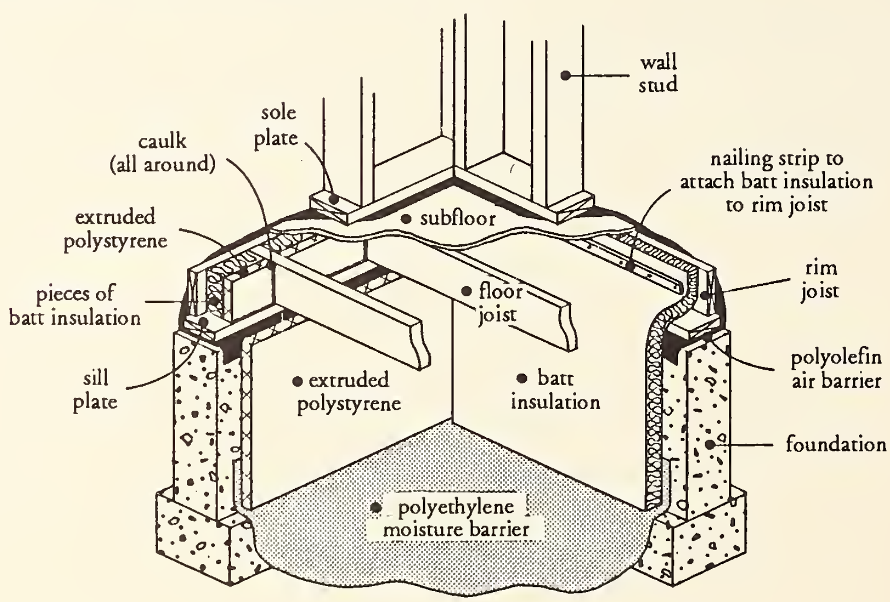
## Crawl spaces

The proper insulation method for a crawl space depends on the plumbing in the crawl space, type of soil, and the potential for problems with radon from the soil. Maximum energy savings is achieved by placing fiberglass batts between the floor joists, using R19 batts for houses heated with gas and R30 for houses heated with electricity. This insulation method reduces the house's heat loss through the floor and allows the crawl space to be ventilated to reduce moisture-related decay hazards and radon problems. (Radon concerns are covered in a later section of this chapter titled "Radon Mitigation.") Heat tape can be wrapped around pipes to prevent them from freezing in ventilated, unheated crawl spaces.

Many people choose to insulate the walls of the crawl space and close the crawl space ventilation during the heating season. This allows heat from the living space to pass downward through the house floor to warm the crawl space and prevent freezing pipes. It may be cost effective to place insulation both on the crawl space walls and between the floor joists over the crawl space, depending on the price of the heating fuel and the type of heating system. Placement of R19 insulation in the floor joists and R11 on the crawl space walls is common in Montana. Many builders use R8 rigid foam board (2-inch expanded polystyrene) on the crawl space walls rather than R11 batts.

A polyethylene moisture barrier is required to prevent the movement of ground moisture into the crawl space. The moisture barrier should be lapped at least 6 inches at all seams. The crawl space vents must be opened in the summer to vent out dampness collected over the winter.

Some cities or counties have code requirements concerning the placement of crawl space insulation and moisture barriers.

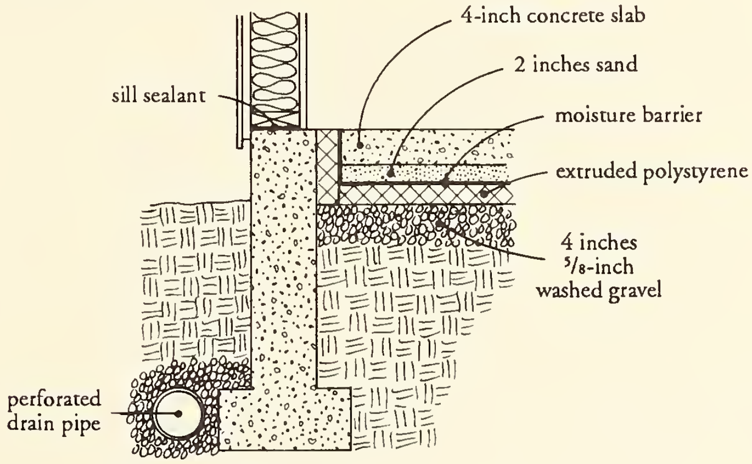



*Typical Insulation in a Crawl Space*

## Slab-on-grade

A well insulated slab-on-grade floor can be an economical floor system for a relatively flat site, especially when the slab can be used to store heat admitted through south-facing windows. With this configuration, linoleum or tile is applied to the concrete as the finished floor surface.

In Montana, the floor slab is typically built as a "floating" slab—one that is inside and separate from the foundation wall. Extruded polystyrene is placed below the slab to control floor heat loss, and applied between the slab and the foundation wall to control heat loss from the edge of the floor slab.



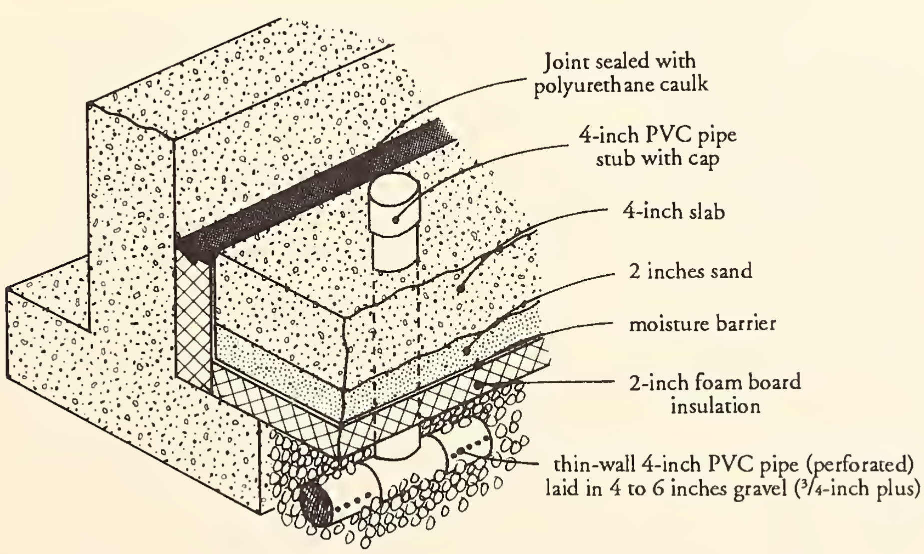

*Slab-on-grade Insulation*

*Taking steps to prevent radon problems in new houses adds little to the construction cost.*

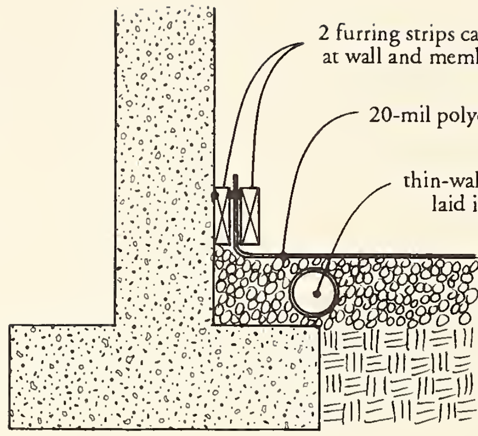
## Radon mitigation

Radon, a radioactive gas, occurs naturally in the soil in some areas of Montana, and can enter houses through basements or crawl spaces. High levels of radon can cause cancer. Testing a site for radon before construction is of no use because placing a house on a site can change the movement of radon in the soil below the house.

Taking steps to prevent radon problems in new houses adds little to the construction cost. The first line of defense against radon infiltration in a house built with a basement is to install at least 4 to 6 inches of clean, coarse gravel under the slab, and to place a short stub of capped PVC pipe through the slab. Some builders also place thin-wall PVC perforated pipe in the gravel base next to the basement footings. The gravel and pipe collect any radon present under the house and vent it to the outside. All cracks and joints in the slab and walls and all openings around utility installations should be caulked with urethane caulk.




*Radon Mitigation in House with Basement*




*Radon Mitigation in House with Crawl Space*

With this sub-slab system installed, the homeowner tests the living space for radon during the first winter in the house. If the test indicates high radon levels, a fan can be attached to the PVC pipe and the radon gas drawn away and vented before it can enter the basement or crawl space.

In a house built over an unheated vented crawl space, radon usually can be kept out of the living space by sealing the floor above the crawl space and making sure the vents are always open. A well sealed floor consists of the tongue-and-groove subfloor glued to joists and glued at the tongue-and-groove joints. Utility penetrations in the floor are sealed with foam or a durable, flexible caulk. Vents in the foundation wall allow radon entering the crawl space to escape to the outside before it can reach the house.

If the crawl space is not ventilated during the winter, then the radon gas must be intercepted before it can enter the crawl space. Since there is no slab, this is usually done by placing gravel under an impermeable membrane in the crawl space. Typically, this membrane is 20-mil polyethylene or a synthetic roofing rubber known as EPDM (ethylene propylene diene monomer). Thin-wall perforated PVC pipe is placed in the gravel base next to the foundation wall. A fan connected to PVC pipe under the membrane removes the radon and vents it outside. The homeowner may want to test for radon the first winter to determine if the pipe, membrane, and fan are necessary.

DNRC has several free publications that discuss strategies for radon mitigation.

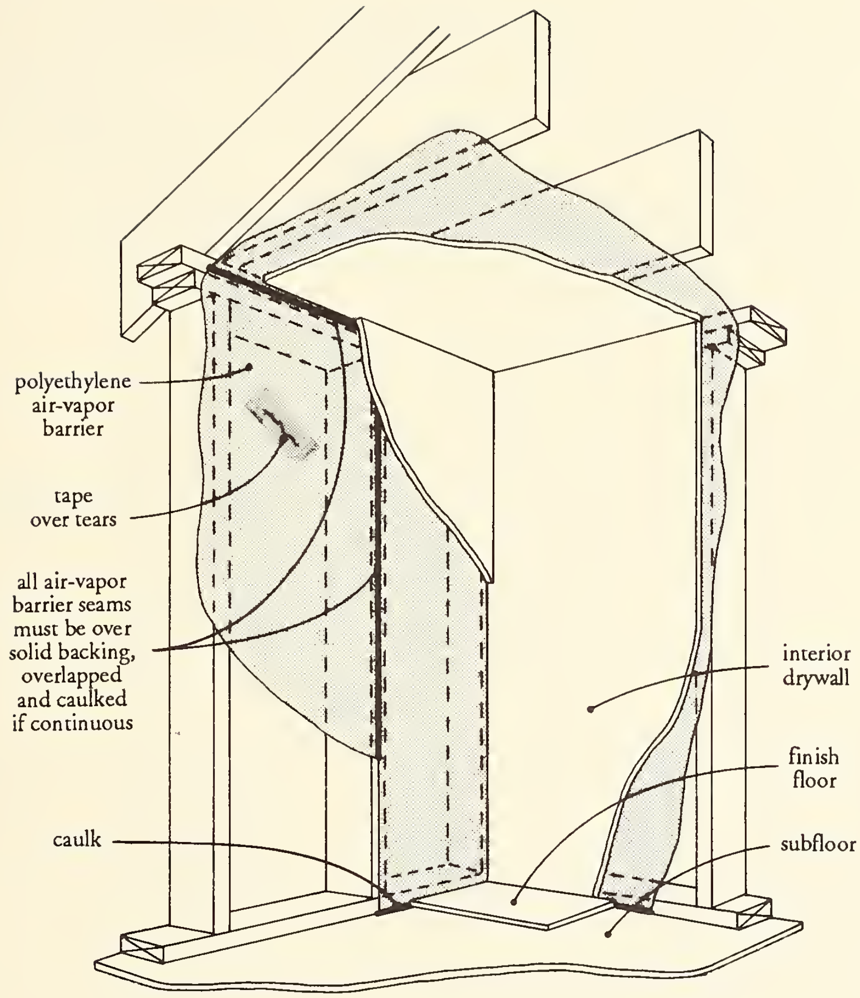
## Air-vapor Barriers

Air-vapor barriers, sealants, and weatherstripping are used to stop convective heat loss. Air-vapor barriers can be polyethylene sheets, gasketed drywall with vapor retardant paint, or foil-faced polyisocyanurate foam board with taped seams.

### Polyethylene

Polyethylene air-vapor barriers should be at least 6 mils thick. Thinner polyethylene is more prone to tearing and damage. Joints of a polyethylene air-vapor barrier must be overlapped at least 4 to 6 inches over solid backing. To make the air barrier continuous, a non-hardening material such as acoustical sealant is used to seal the joints.

The air-vapor barrier must be within the "warm" portion of ceilings and walls so water vapor from the inside is stopped before it cools enough to condense in the insulation.




*Polyethylene Air-vapor Barrier*

### Airtight drywall

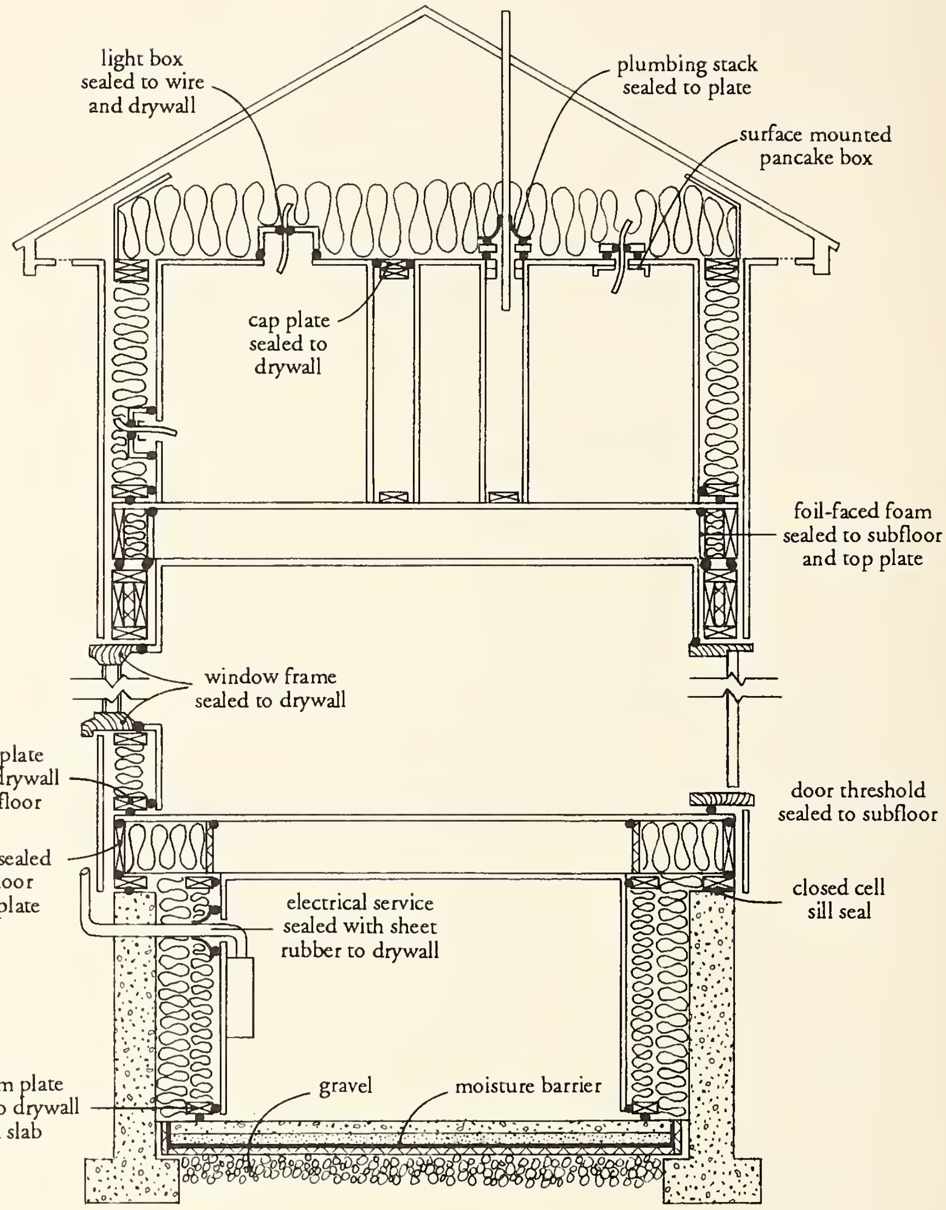
An alternative to polyethylene is the airtight drywall approach (ADA). In this approach, the drywall acts as the air barrier. It is taped and mudded at the seams in the usual way, and sealed to other building components with caulk or gaskets to make it airtight. Low-permeability paint applied to the interior surface of the drywall serves as a vapor retarder. Any cracks or openings in the drywall are readily visible and can be repaired easily to maintain airtightness.

### Polyisocyanurate foam board

Foil-faced rigid foam board used as interior insulation can also serve as an air-vapor barrier if the seams are taped with aluminized or 3M Contractor Sheathing Tape.

## Sealing Penetrations

A complete, well-sealed air-vapor barrier is difficult to install because of light fixtures and outlets, plumbing vents and pipes, and other wall penetrations. The obvious first step is to prevent unnecessary holes in the barrier. Steps for accommodating the air-vapor barrier are listed below.




*Continuous Airtight Drywall Air-vapor Barrier*

## SEALANTS, WEATHERSTRIPPING, AND TAPES

Sealants are used to close openings where building components meet. The five types of sealants are: caulking, expanding foam, gasketing, adhesives, and acoustical sealant. Caulk is used to fill in the small cracks. Frothy expanding foam is used for large uneven openings such as around window and door frames, plumbing, and electrical openings that caulking compounds cannot fill. Gasketing is used to stop air leakage between foundation and sill, sill and rim joist, rim joist and plywood subfloor, subfloor and bottom plate, and behind drywall. Adhesives are used to fix rigid insulation to masonry foundations. Acoustical sealant , a non-hardening, gummy material, is used to seal sheets of polyethylene to one another and to plastic electrical boxes.

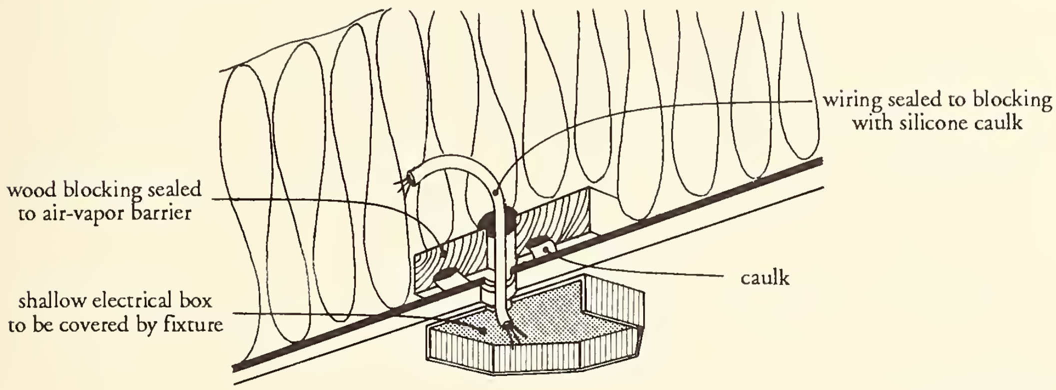
Weatherstripping is used to control air leakage at joints where moveable surfaces meet, such as in windows and doors.

Tapes are used to seal joints in insulating sheathing, Tyvek, polyethylene, flashings, headers, and sill plates. Tapes that stick well include aluminized tape and 3M Contractor Sheathing Tape.

## Electrical

To eliminate electrical wiring penetrations of the ceiling, use wall-mounted fixtures, or lights mounted on the ceiling surface or a track. Recessed lights in insulated ceilings are difficult to seal because they must be ventilated to the attic for cooling. Surface-mounted "pancake" boxes permit ceiling fixtures with only small holes in the ceiling.

An air-tight seal on the electric service entrance requires sealing the opening for the main service conduit and the opening for the wiring into the exterior walls.

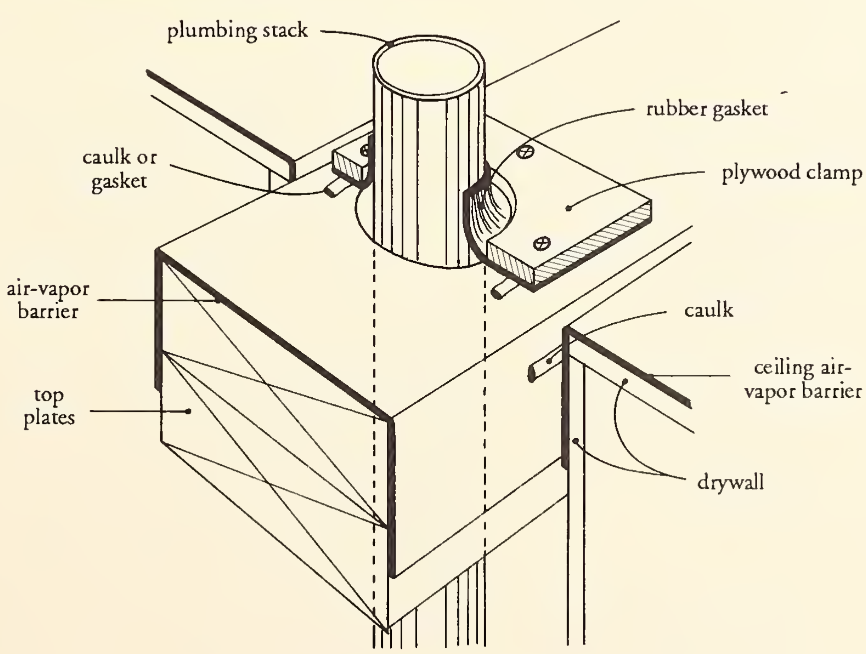



*Surface-mounted Ceiling Electrical Box*

## Plumbing

Plumbing penetrations in the air-vapor barrier can be minimized by placing plumbing fixtures on interior walls. Some penetrations such as plumbing stacks are necessary "punctures" in the ceiling and floor of a house, and must be well sealed to the air-vapor barrier. One method is to caulk a patch of sheet rubber to the ceiling or floor air-vapor barrier and secure it to the plate with a nailer plate. Neoprene roof jacks can also be used for this application.

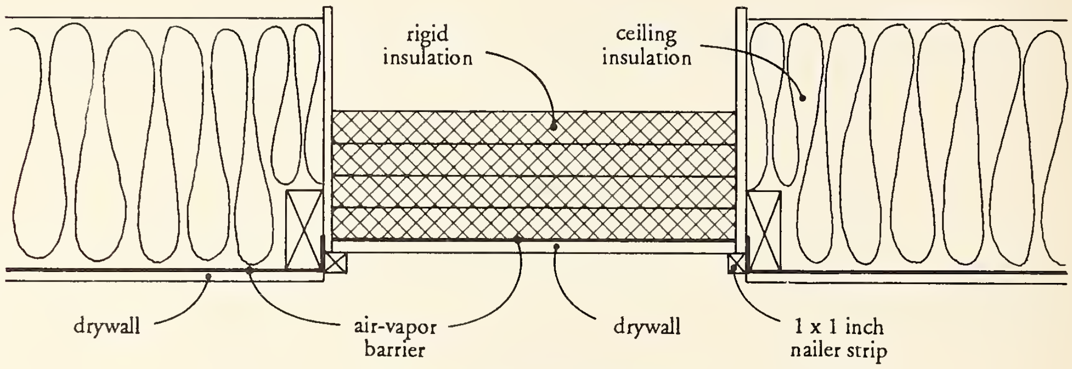
Metal firestops properly insulated and sealed have to be used to control air leakage around chimneys.




*Sealing a Plumbing Stack*

### Attic hatch

Many houses have an attic access hatch in their ceiling. If is best if the hatch is eliminated from the interior and placed on an outside gable end or through an unheated garage. If this placement is not possible, the hatch should be insulated to the R-value of the ceiling and its edges weatherstripped.



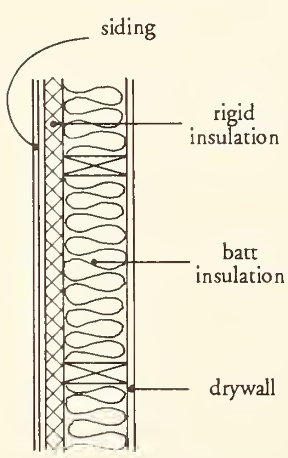

*Attic Hatch Detail*

### Windows and doors

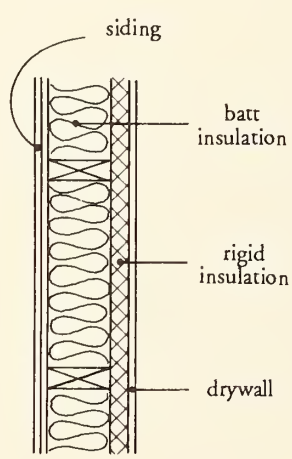
Even the best windows and doors if treated roughly and installed in a skewed rough opening can leak considerable amounts of air. The best defense against a leaky window or door is to foam the rough openings around the frame.

## Exterior Walls

Wall designs that accommodate high levels of insulation (R27 or more) include: (1) a single stud wall with foam board insulation, (2) a single stud wall with strapping, (3) a staggered stud wall with foamed-in-place insulation, and (4) a double stud wall. The single 2 x 6 stud wall with foam board insulation or strapping has a practical limit of about R30, whereas the staggered stud and double stud walls can be constructed to exceed R40.




*Single Stud Wall with Exterior Rigid Insulation*



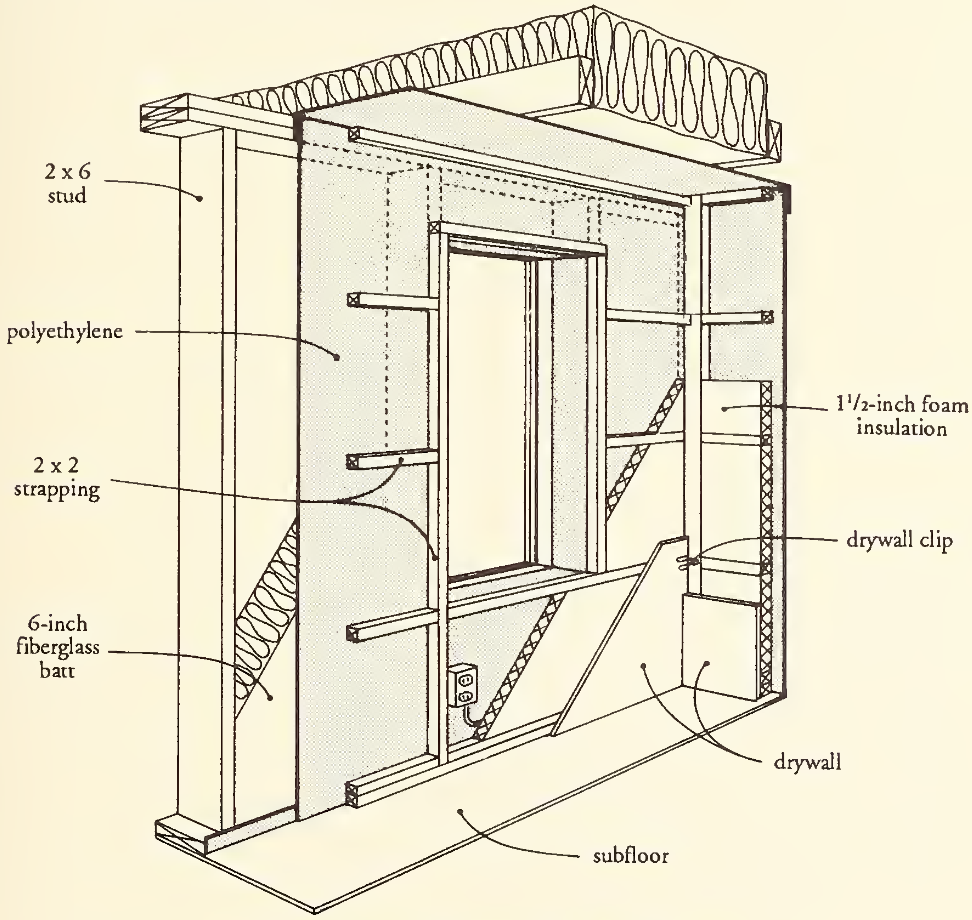

*Single Stud Wall with Interior Rigid Insulation*

### Single stud wall with foam board insulation

Stud walls are commonly built to a single stud thickness and their cavities filled with fiberglass batts or blown-in-batts. Increasing the insulation by installing 1-inch rigid foam board over the studs achieves an R-value above the R19 minimum HUD standard and prevents conduction of heat through the studs. Foam board insulation can be placed on the interior or exterior surface of the walls. Placing foam board insulation on the interior and taping the seams with aluminized or sheathing tape will also allow the insulation to serve as an air-vapor barrier.

## Single stud wall with strapping

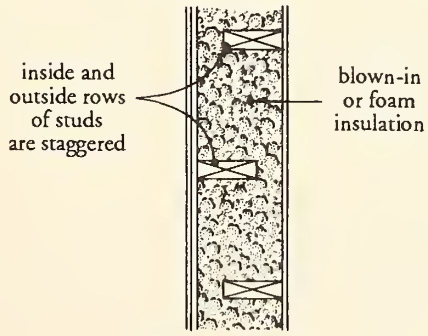
Nailing 2 x 2 strips (strapping) to the interior side of a single-stud wall allows room for additional insulation and provides a convenient cavity for wiring or plumbing. Besides preventing thermal conduction through the wall studs, this method can prevent damage to the polyethylene air-vapor barrier.




*Single Stud Wall with Strapping*

## Staggered stud wall

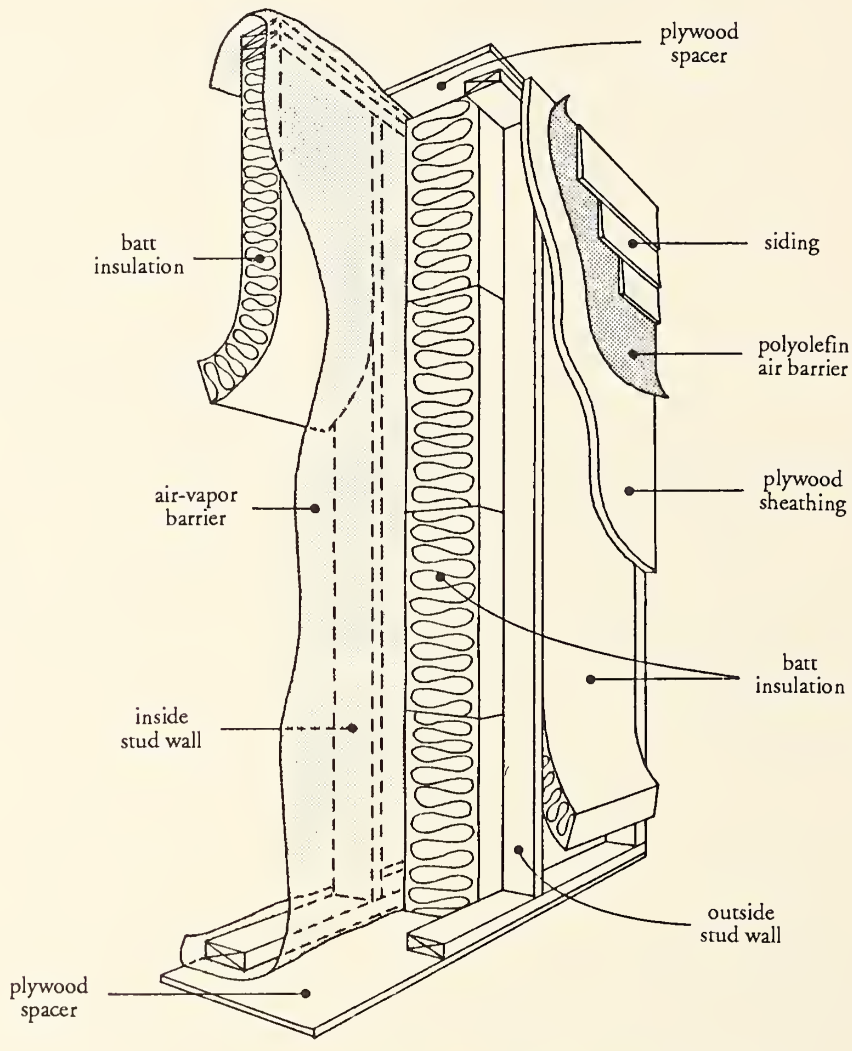
Another method to provide space for increased wall insulation is to use plates wider than the studs and stagger the studs to prevent heat conduction through the studs. Filling the stud cavity with foamed-in-place urethane provides R7 per inch of insulation and the foam also acts as an air-vapor barrier. If batts or loose fill insulation are used, however, an air-vapor barrier is still needed on the interior.




*Staggered Stud Wall*

## Double stud wall

Double-wall construction provides a thick wall cavity for plenty of insulation and protects polyethylene air-vapor barriers by isolating them inside the wall assembly. A double wall normally consists of two 2 x 4 stud walls with a space between them. This space is usually 4 to 6 inches, which allows room for R11 or R19 batts between the walls and R11 batts within the cavities between studs. The polyethylene air-vapor barrier is placed on the back side of the inner wall (away from the living space). All electrical and plumbing work can be installed in the inner 2 x 4 wall without penetrating the air-vapor barrier.




*Double Stud Wall Construction*

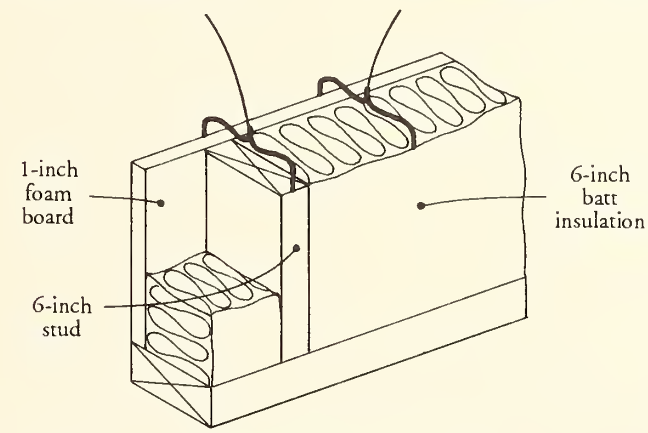
Double walls can be built in a variety of configurations. Different contractors use different methods, depending on their preference and equipment, on local codes, and on the amount of insulation desired.

## Advanced framing

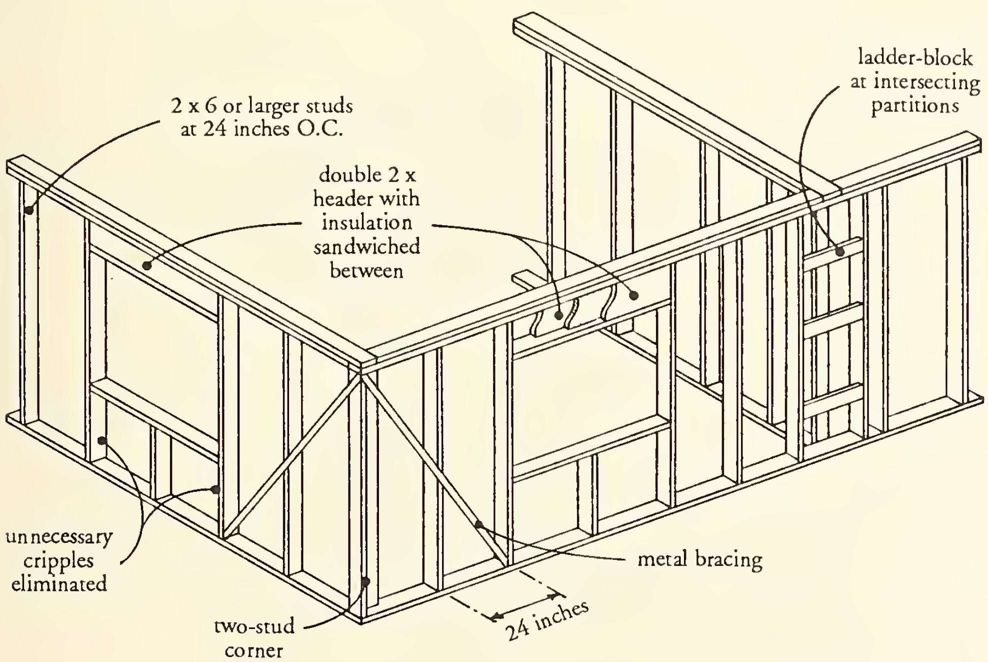
Wood in a house's exterior walls and ceilings is one avenue of heat loss from the interior. Wood has an R-value of only 1.25 per inch compared to foam or fiberglass with R-values of 3.5 or more per inch. Consequently, where studs displace insulation, the R-value is lower, reducing the overall insulation value of the wall.

To reduce the amount of wood in the structure of a house, and maximize the amount of insulation in the walls and ceiling, a technique known as *advanced framing* can be used in most localities (check with your local building code office). In this configuration, the studs are set on 24-inch centers. The corners have two studs rather than three, with strips of metal for bracing. Rather than solid headers over doors and windows, headers are made of two boards with rigid insulation sandwiched between. The building shell constructed with advanced framing holds heat efficiently and saves material costs. Walls framed at 16 inches on center are usually about 20 percent wood and 80 percent insulation. Advanced framing techniques improve that ratio to 12 percent wood and 88 percent insulation, with no loss of structural stability.

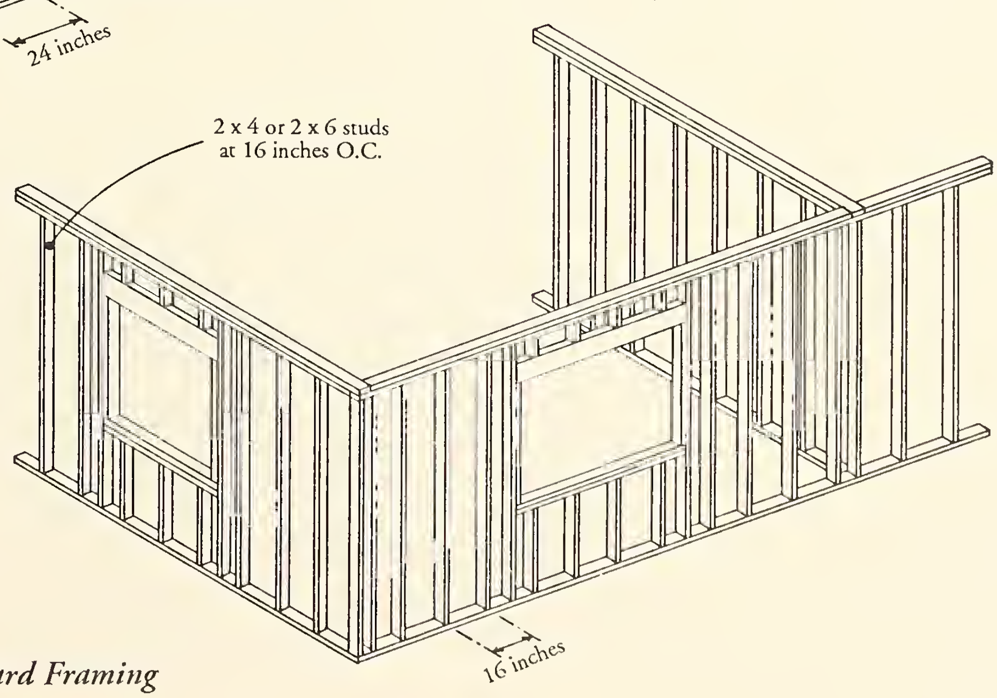
| Material | R-value | Material | R-value |
|---|---|---|---|
| 1-inch foam board | 7.4 | 1-inch foam board | 7.4 |
| 6-inch stud | 7.5 | 6-inch batt insulation | 19.0 |
| total | 14.9 | total | 26.4 |




*Calculating R-values*




*Advanced Framing*

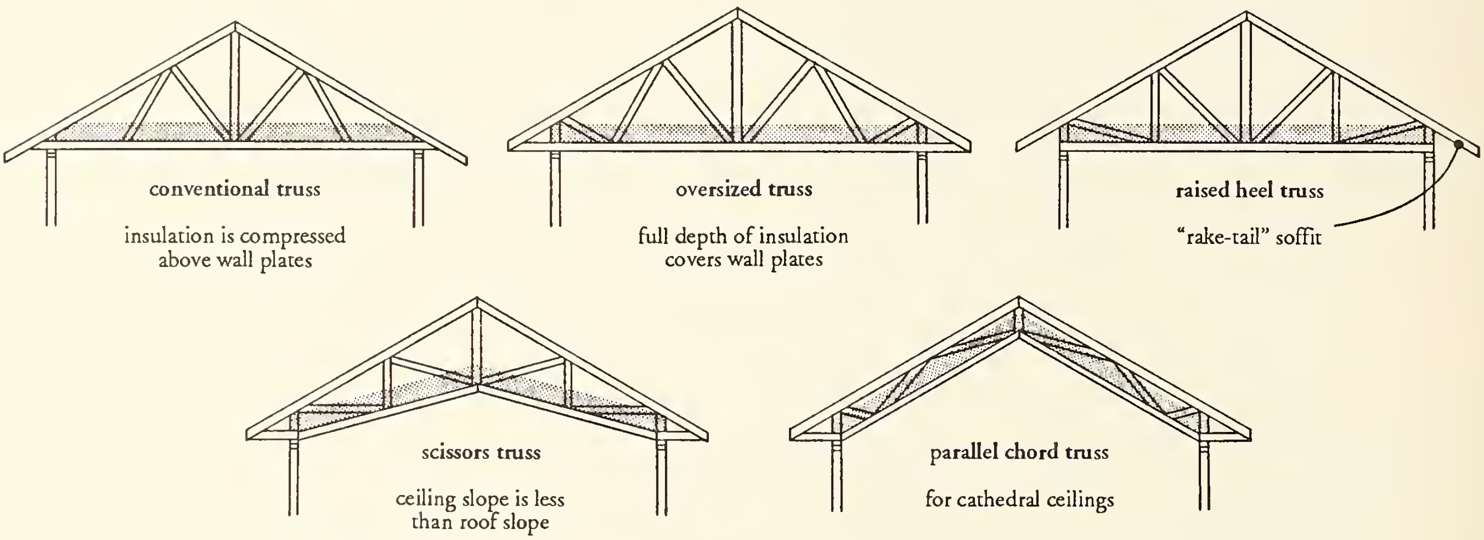



*Standard Framing*

## Ceilings and Roofs

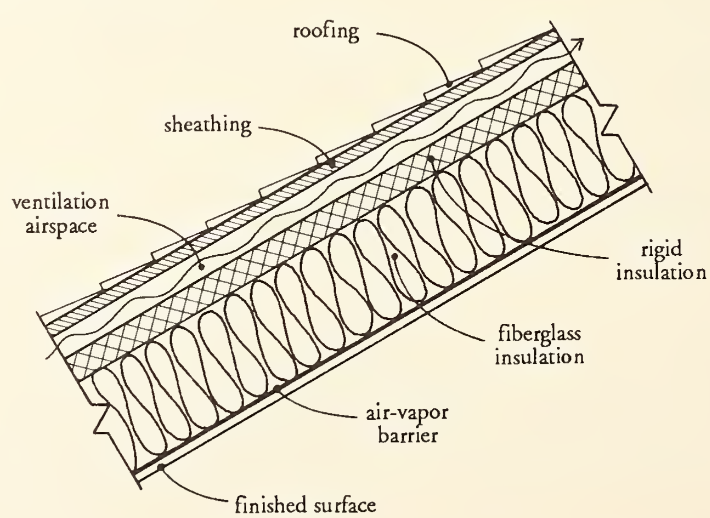
More insulation is recommended for ceilings than for walls. The attic in a house with a slanted roof and flat ceiling normally provides ample room for R40 to R60 insulation, except at the edge over the exterior walls. New houses can be built with oversized truss rafters to increase the depth at this point. In some cases, however, special framing methods at the eaves of the roof (for example, raised-heel trusses) may be required to allow full depth of insulation to extend over the outside wall.

Insulation in houses with attics is usually blown-in loose fill, or batts. Insulation in cathedral ceilings can be foam or batts or a combination.




*Trusses*

Cathedral ceilings should have a tight air-vapor barrier installed in the ceiling, with 10 to 12 inches of fiberglass insulation placed above the barrier. Foam insulation should be placed on top of the rafters. An air space between the roof and the insulation, provided by 1 x 2s laid over the insulation and nailed to the rafters, ventilates the roof, reducing the risk of ice damming in the winter and roof overheating in the summer.




*Cathedral Ceiling Construction and Ventilation*

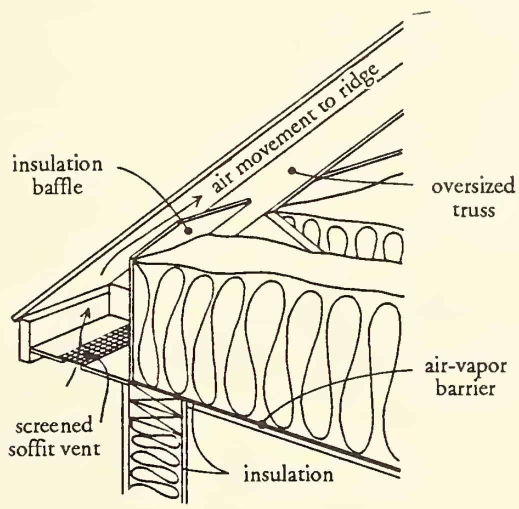
### Attic ventilation

Ventilation between ceiling insulation and the roof removes water vapor that escapes into the rafter cavity from the heated living space; it keeps the outer roof surface cold, thus minimizing snow melt and ice formation above the eaves; and it helps to cool the roof during hot weather.

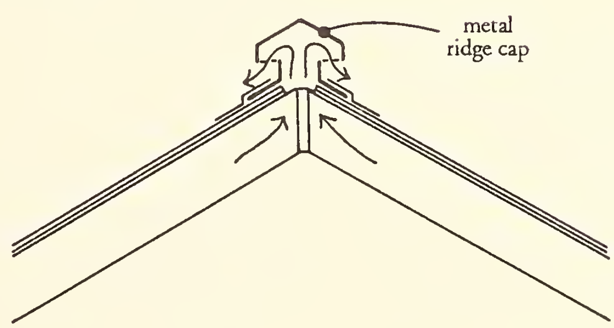
In most areas, one square foot of net free vent space must be provided for every 300 square feet of ceiling area, evenly divided between soffit vents and gable vents. The recommended ventilation for energy-efficient houses in Montana is a continuous soffit ventilation strip in conjunction with a continuous ridge vent.

A baffled ridge vent that deflects wind is usually most suitable in Montana. The baffles increase the airflow from the attic and prevent entry of water and snow. Good quality ridge vents are made of metal or molded polyethylene and have integrated baffles.

The energy efficiency of roofs and attics can usually be improved by installing an insulation baffle at the eave to prevent wind from blowing through the insulation. Wind blowing through insulation reduces dead air spaces and sets up convective loops, reducing the insulation's effectiveness.



*Continuous Soffit Vent*



*Continuous Ridge Vent*

## Siding

Placement of rigid foam board insulation on the exterior is becoming common. Although foam board is effective insulation, it does not provide structural bracing as plywood does. Therefore, codes require some form of wind bracing when plywood sheathing is not used.

If a good interior air-vapor barrier is installed, external insulating sheathings do not cause significant moisture accumulation in walls. Openings in the sheathing allow vapor to diffuse from the wall cavity to the exterior.

Unless the manufacturer directs otherwise, wood or hardboard siding should not be directly applied over foam installation, because paint failure or warping may occur. Siding installed improperly over any material can cause these problems. However, warping and paint failure are more likely when siding is directly applied over foam, because the siding tends to get hotter in the day—particularly on the sunlit sides—and colder at night, which can cause excessive expansion and contraction. To minimize temperature swings, siding can be nailed to 1-inch furring strips

placed over the foam sheathing to leave an air space. The best defense againsst siding problems of any type is to use quality siding and install it according to the manufacturer's directions to preserve the warranty. Guidelines may also be obtained from the National Forest Products Association and The Society of the Plastics Industry, Inc., listed in the *More Information* section at the end of this book.

## Exterior Air Barrier

A material or combination of materials is often used between the siding and the exterior of a building to block infiltration of outside air while letting moisture vapor pass from inside through to the outside. Materials commonly used in Montana are spun-bonded polyolefin such as Tyvek, and cross-laminated high-density polyethylene with tiny holes such as Rufco-Wrap or Tu-Tuf Air Seal, and felt. These air barriers do not add any insulating value. Taping the seams of rigid foam board also forms an air infiltration barrier.

# Mechanical Systems

Mechanical systems should be part of the initial house design. A design that accommodates ductwork, piping, and space for heating, ventilation, and water heating systems can reduce equipment and installation costs, and provide optimum performance and comfort.

The ventilation system and the heating system should be designed and installed by the same contractor where practical. If this isn't possible, each contractor should be supplied with the detailed plans and specifications for all mechanical systems so the systems can be coordinated and properly installed.

*Installing the smallest capacity heating equipment that can meet the heating load will save both energy and money.*

## Heating Systems

An energy-efficient house loses little heat because it is well insulated and reasonably airtight. Heat given off by appliances, lights, and people will contribute to the space heating, and the sun will add warmth on clear days. The lower heating needs mean that the energy-efficient house requires a smaller, less expensive heating system than required by a conventional structure of the same size. Installing the smallest capacity heating equipment that can meet the heating load will save both energy and money.

Analyzing the heat loss is critical for determining the proper size of the heating system. Heat-loss analysis requires a surface-by-surface inventory of heat loss through the building materials. Many heating contractors have computer programs that perform this analysis.

If outdated, rule-of-thumb calculations are used to size the heating system, there can be several undesirable results. Typically, the equipment will be oversized, expensive, and space consuming. In a combustion-type forced-air system, the efficiency of the heating plant will be severely reduced because the system will cycle on and off for short periods of time. When a combustion furnace turns on, the heat exchanger takes a certain amount of time to reach operating temperature and peak efficiency. If the system is oversized, it won't run long at this maximum efficiency before it warms the house to the desired temperature. Then it will shut down, sending much of the heat stored in the heat exchanger up the chimney and leaving some heat in the delivery ducts. For best performance and longest life, heating equipment should be sized to operate at full capacity for long periods.

Generally, one of three basic types of heat distribution systems are used in a house:

- central forced air,
- individual room heaters,
- radiant heaters.

The most appropriate choice is based on preference, local fuel sources, installation costs, and performance. In some cases, a combination of systems may prove to be the best method for heating a house.

Forced-air systems are commonly fired with natural gas, propane, or oil, although electric forced-air furnaces are available. In airtight houses, air from outside must be ducted to combustion systems to prevent depletion of oxygen inside the house. For gas-fired devices, spark ignition systems should be installed to eliminate gas-wasting pilot lights.

A free book available from DNRC, *Gas Furnaces and Appliances: Sorting Through the Options*, discusses heat plant sizing and energy-efficient gas furnaces.

Electric or hydronic baseboards and other individual room systems have the advantage of allowing the temperature to be independently controlled for each room. Most individual room units either have no fan or a small one, so are generally quieter than a central forced-air system.

Electric heating units include variations of baseboard convection heaters and radiant heating cables and panels. One significant consideration when selecting the type of electric unit is the surface temperature of the heating element.

Hydronic heating systems fired by gas boilers and circulating hot water through baseboards or coils in a concrete floor are becoming popular. As with combustion furnaces, the boiler must have a supply of combustion air from outside to prevent depletion of oxygen from the house.

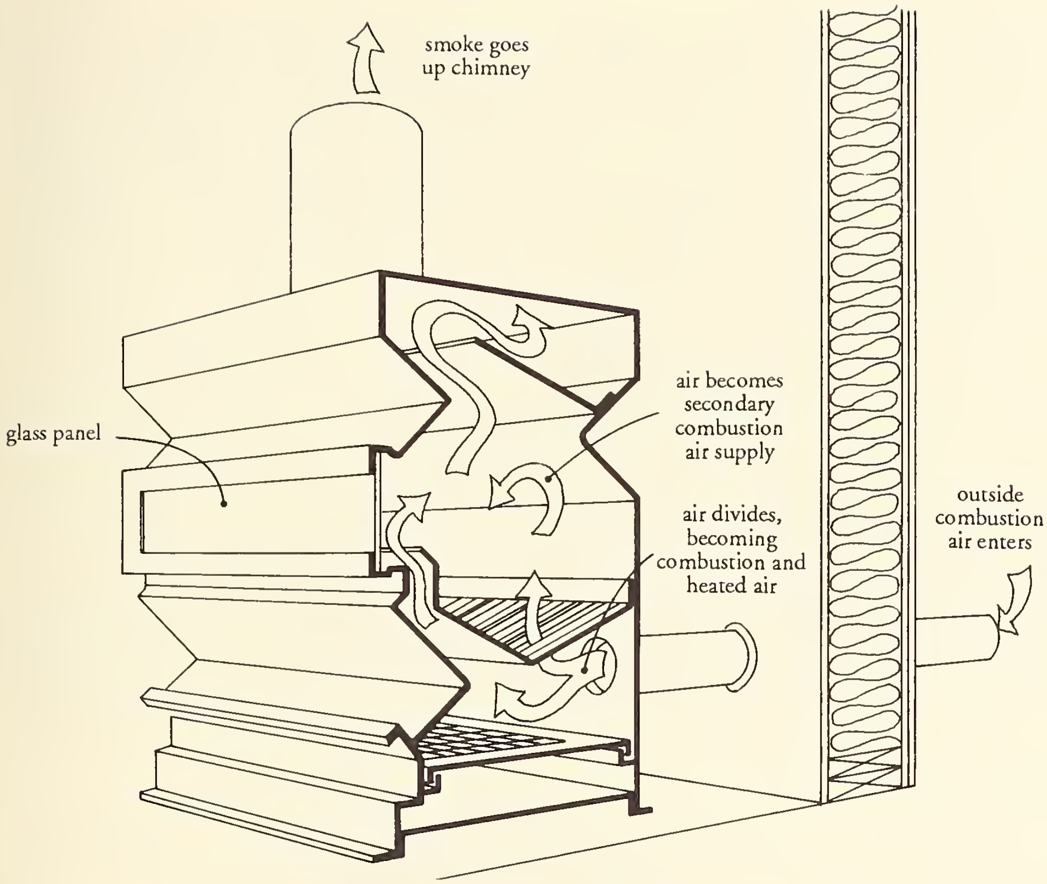
Heat pumps extract energy from water, air, or ground and release heat to indoor living spaces. Heat pumps that extract warmth from air are not recommended in most Montana climates, because heat is needed mostly when air temperatures fall below the range where the heat pump is able to efficiently operate. These units operate best at mild outdoor temperatures, with 35 degrees F about optimum. Heat pumps that extract warmth from the ground or water can operate more efficiently than air-source heat pumps. These units are generally more expensive than other heating systems, however.

Heating systems that burn wood or other solid fuel can be used under certain conditions. A major concern is the contribution to air pollution both inside and outside the house. It is essential that the burner be equipped with tight-fitting doors, dampers and chimney connectors, and, most important, that combustion air be piped to the unit from outside.

Fireplaces are inefficient heating units and demand high volumes of air. Conventional fireplaces must be equipped with tight-fitting glass doors and an outside air intake into the fire chamber to avoid backdrafting and the loss of warm room air up the chimney. The fireplace should be located away from outside walls. *Wood Heat*, a free publication from DNRC, discusses fireplaces in detail.

### Setback thermostats

Thermostats that automatically turn down the heat at night and turn it up in the morning offer a simple way to save energy. Some thermostats can control both heat and air conditioning for year-round savings. Electromechanical thermostats that use a clock-timer have proven convenient and reliable. Computerized




*Wood Stove with Outside Combustion Air*

thermostats and programmable controllers should be carefully evaluated for ease of operation and compatibility with the heating system. Most manufacturers have lists of thermostats that are compatible with their equipment.

*It may seem illogical to deliberately bring in outside air after taking care to build an airtight house, but it's necessary.*

## Ventilation Systems

The tight construction of an energy-efficient house requires a controlled ventilation system. It may seem illogical to deliberately bring in outside air after taking care to build an airtight house, but it's necessary to help ensure that common contaminants, odors, and humidity are kept at acceptable levels.

A controlled ventilation system has significant advantages over haphazard natural air leakage. It exhausts air from rooms where humidity and odors are generated and supplies fresh air to ensure that each room and the entire house gets a periodic washing of fresh air. Relying on natural ventilation could require several hours for the air volume in the house to escape and be replaced by air from outside. Even in a conventional house where natural ventilation usually causes one or more air changes per hour, there are times when no air is moving through the house.

Controlled ventilation systems come in two types: ventilation with heat recovery or ventilation without heat recovery.

### HUMIDITY

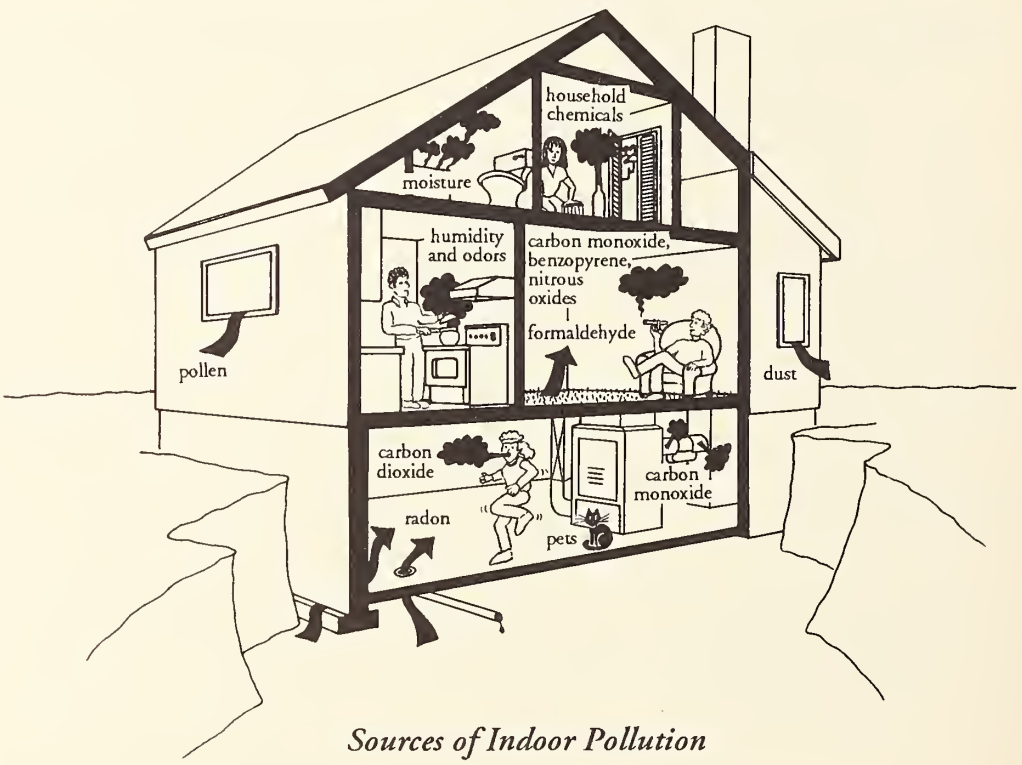
Controlling humidity through adequate ventilation minimizes the amount of water vapor that could move into walls, ceilings, or floors. If excess vapor from the interior is allowed to enter an insulated wall or ceiling during cold weather, it could condense and freeze at some point within the wall (this point is called the "dew" point). When the ice melts, wetting and subsequent deterioration of the insulation and structural components can occur.

## VENTILATION AND AIR CHANGES PER HOUR

The replacement of stale, humid indoor air with fresh outdoor air is called ventilation. **Natural** ventilation describes air exchange occurring intentionally or unintentionally through cracks in the envelope of the house or through windows or doors. **Controlled ventilation** refers to air exchange created by fans or by natural draft through fresh air ducts in the house's envelope.

Ventilation rate is the time it takes for inside air to be replaced by outside air. An air change rate of one-half air change per hour (ACH) means that half the volume of air in the house is exhausted and replaced by fresh air each hour. The recommended controlled ventilation rate for a house depends on its volume, natural ventilation rate, number of occupants, type of construction materials, moisture sources in the house, and building code requirements. Generally, the recommended controlled ventilation rate is between 0.35 and 0.6 air changes per hour, which results in a complete air change every 2 to 3 hours. Controlled ventilation systems usually don't operate continuously, but are set to switch on for a short period every hour, or for several hours at a set time each day or night, or when air moisture builds up.

The amount of air brought in or exhausted by controlled ventilation is measured in cubic feet per minute (cfm). The volume of air in a 2000-square-foot house is about 16,000 cubic feet. Thus, to change one-third to a little over half of that air every 60 minutes requires a total ventilation rate of 85 to 160 cfm.



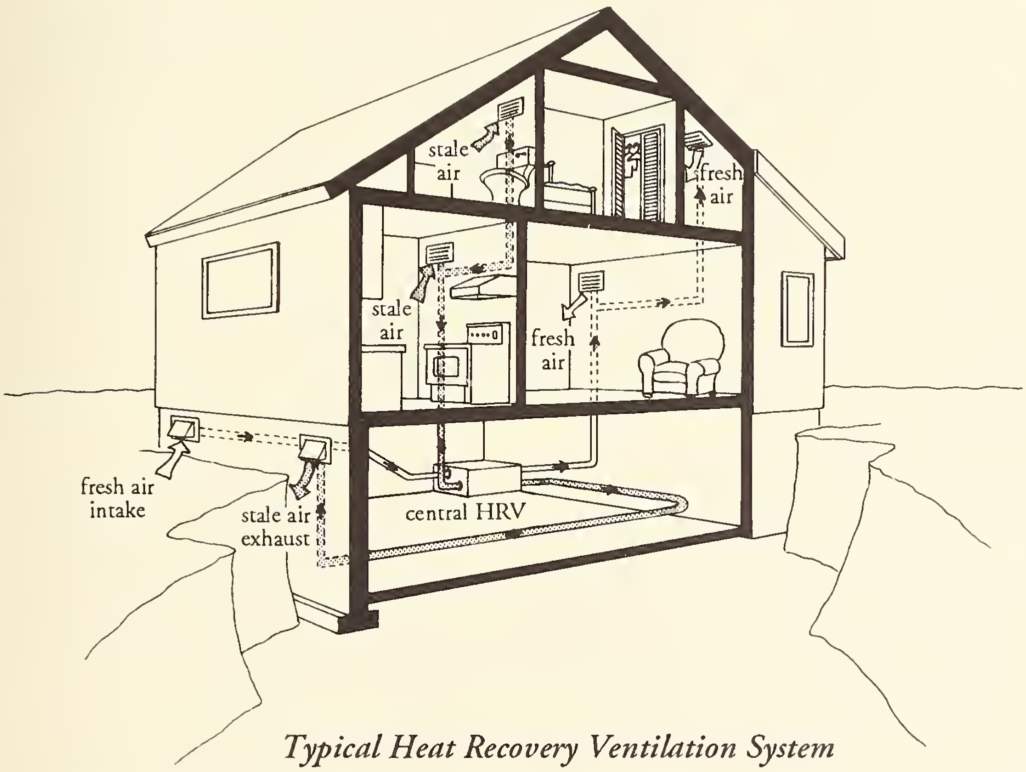

*Sources of Indoor Pollution*

### Ventilation with heat recovery

Ventilation with heat recovery relies on a heat exchanger to transfer some of the heat from stale outgoing air to the cooler incoming air or to the domestic hot water system. Basically, fresh incoming air is distributed through ducts to living zones and stale air is exhausted outside.

These systems have definite advantages, although they are more costly and require a more complex ductwork than non-heat recovery ventilation systems. Heat recovery ventilator (HRV) systems save energy by recovering some of the heat from the exhaust air. An air-to-air heat recovery ventilator can recover about 50 percent of the heat; an air-to-water exhaust air heat pump system can recover 30 to 50

percent. An HRV can run continuously or at set intervals on low speed to ensure uniform indoor air quality. The HRV also may be manually switched on or switched to high when odors build up, such as cigarette smoke during a party. In summer months, heat can be removed from incoming fresh air, reducing the cooling needs. Furthermore, incoming fresh air to the HRV is filtered. Therefore, less dust and dirt enter the house when using the HRV to ventilate the house than when opening windows and doors for ventilation.



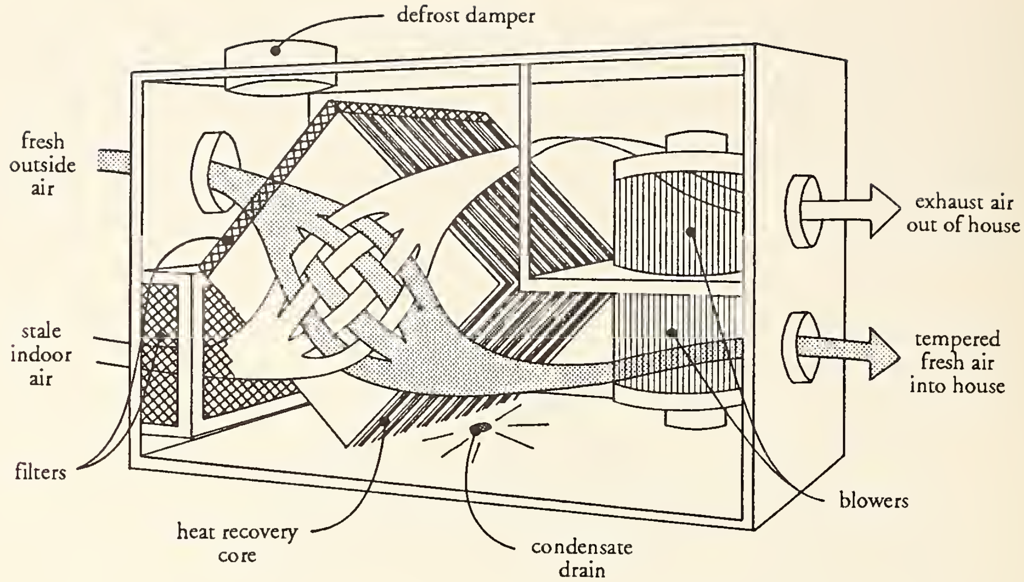

*Typical Heat Recovery Ventilation System*

Most ventilation systems in new energy-efficient houses in Montana are designed to recover heat from stale indoor air that is being exhausted to the outside. Heat-recovery is accomplished with heat-recovery ventilators (HRV) which can be set up to operate alone, or in combination with either a hot water heater or forced-air heating system.

Stand-alone HRV systems are most common. These systems consist of a variable speed fan, a heat exchanger where cool outside air on its way in is passed by the warm air on its way out, and a system of ducts that ventilate different rooms. A heater in the fresh air intake duct may be used to warm the incoming air.

New on the market are exhaust air heat pumps that extract heat from the outgoing stale air and use it to heat water for use in the house. Fans draw stale air from kitchens, bathrooms, and utility areas. The air travels through ducts to a heat exchanger coupled to the water heater. As the air passes through the heat exchanger to the outside, heat is extracted from the air and used to warm the water. Fresh air enters the house through special openings in the wall. Other configurations combine the HRV with the heating system.

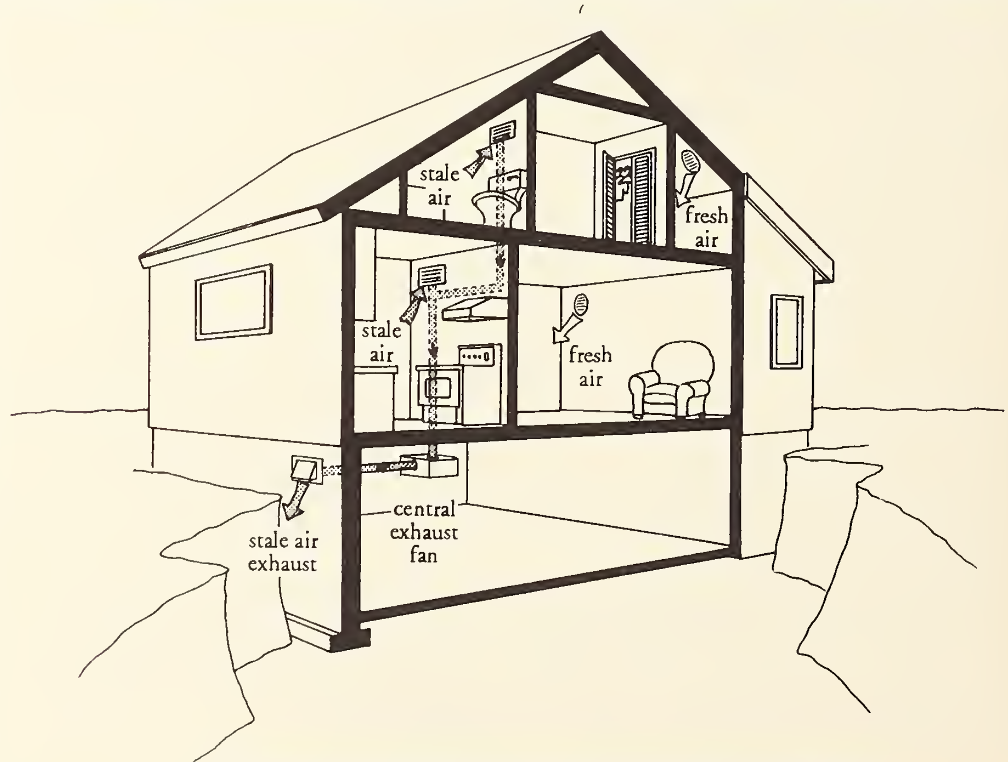
Heat recovery ventilators are available "off the shelf," but determining the proper system for a given house is a job for a qualified specialist who is familiar with these systems. Only a heat recovery ventilator that has been tested and shown to operate efficiently in Montana's climate should be installed.




*The ventilation system's heat exchanger transfers heat from exhaust air to intake air*
***Heat Recovery Process***

## Non-heat recovery ventilation systems

Systems that exhaust air and bring in makeup air without preheating it are cheaper to install than heat recovery systems. They should be used only in electrically heated houses or in houses where all combustion devices have combustion air delivered directly to them from the outside. When exhaust fans are turned on in airtight houses, dangerous gas and fumes can be drawn into the living space through chimneys or exhaust flues of fireplaces and other combustion devices. This is known as "backdrafting," and can be prevented by piping combustion air from outside. Ventilation systems without ducting may not distribute air evenly and pockets of uncirculated, polluted air may cause problems. Again, several




***Typical Ventilation System without Heat Recovery***

methods can be used. One employs quiet, high capacity fans at points where moisture and odors are generated (kitchen, baths, and laundry) to exhaust stale air to the outside. Another uses a central exhaust fan. The fans operate when humidity in the house reaches a certain level. The fans also can be turned on manually.

In all cases, fresh make-up air comes through special inlets in the building shell, usually through ports in the outside walls. The ports are mounted at strategic locations high on the walls of bedrooms and living spaces to bring in outside air. Once inside, the cool air falls down the walls and mixes with the warm room air. Extensive ductwork is not needed. Many of the inlets automatically adjust the opening to provide fresh air independent of wind pressure, and some also have controls that introduce more air when the inside humidity rises.

Fresh air also can be introduced through forced-air heating systems or by natural draft through earth tubes, although these are not common practices in Montana.

Ceiling-mounted exhaust fans should be avoided. Air leakage around these units is difficult to prevent and their built-in dampers often let warm air leak out. They usually vent through the attic where leaking warm air may cause condensation. Exhaust fans optimally should be installed on interior walls with ducts routed down the wall and out through a basement (or through a rim joist) on a downward draining slope.

## Domestic Water Heaters

Heating water may consume more energy than is used for space heating or for lights and appliances. Only the most efficient water heaters should be used.

The two basic types of water heating systems are those that heat the water and store it in a central tank, and tankless heaters that heat water only as it is used. The tank system is more common. Water heaters that burn oil or gas must have outside air piped to them. A single, properly-sized air supply can provide air for both a space heating unit and a water heater. Because no amount of insulation will totally prevent heat loss from a hot water tank, it is always best to locate the tank in a heated space.

Instantaneous heaters can be located near a point of use, or centrally located among hot water taps. They can be used alone, or to boost the capacity of a hot water tank system. Burners in instantaneous heaters are activated by flow sensors when a hot water spigot is turned on, and the water is heated as it is drawn through a heat exchanger. Newer models have heaters sensitive to both the temperature and rate of water flow, modulating the flame to produce more or less heat. The capacity of some instantaneous heaters will be exceeded unless hot water use is coordinated, avoiding simultaneous shower and dishwasher use, for example. Instantaneous heaters do not work on well systems because the pressure tank and well pump don't allow water to flow at a steady rate. Higher initial costs of instantaneous units may be offset by lower operating costs over the life of the unit.

More information on hot water heating systems may be found in free books from DNRC entitled, *The Montana Energy Book, Hot Water—Insulate and Save!,* and *Gas Furnaces and Appliances—Sorting Through the Options.*

# Home Energy Management

The homeowner can make a significant impact on the energy use of the house. Doors left open or thermostats turned up increase energy consumption. If two houses were built and occupied identically with one having a thermostat setting of 70 degrees F, and the other of 65 degrees F, the building with the 65 degree setting would use about 20 percent less energy per year. Choosing energy-efficient appliances, controlling space heat, using efficient lighting, and consuming less water offer energy savings for little investment of time, effort, or money.

*In a 1400-square-foot house, a refrigerator typically consumes almost twice the energy of lighting.*

### Appliances

Appliances usually last many years, and the extra dollars spent initially for energy efficiency can be offset by years of savings. All major residential appliances must be labeled showing how that particular appliance compares to others on the market in energy use per year. This information should be used to select energy-efficient appliances and water heaters. A free pocket guide from DNRC, "*Cold Facts, Hot Ideas*," helps interpret the yellow EnergyGuide labels on appliances.

In a 1400-square-foot house, a refrigerator typically consumes almost twice the energy of lighting. It should be the first appliance judged critically for energy efficiency. To optimize energy savings, the refrigerator should not be placed next to a range.

The efficiency of washing machines can be increased by using cold water when possible and washing full loads or using the water level control for smaller loads.

### Space heating

Turning down a thermostat a few degrees during the day will save heating energy. Setting it even lower at night offers more savings. Closing curtains and shades at night helps prevent the loss of heat through windows.

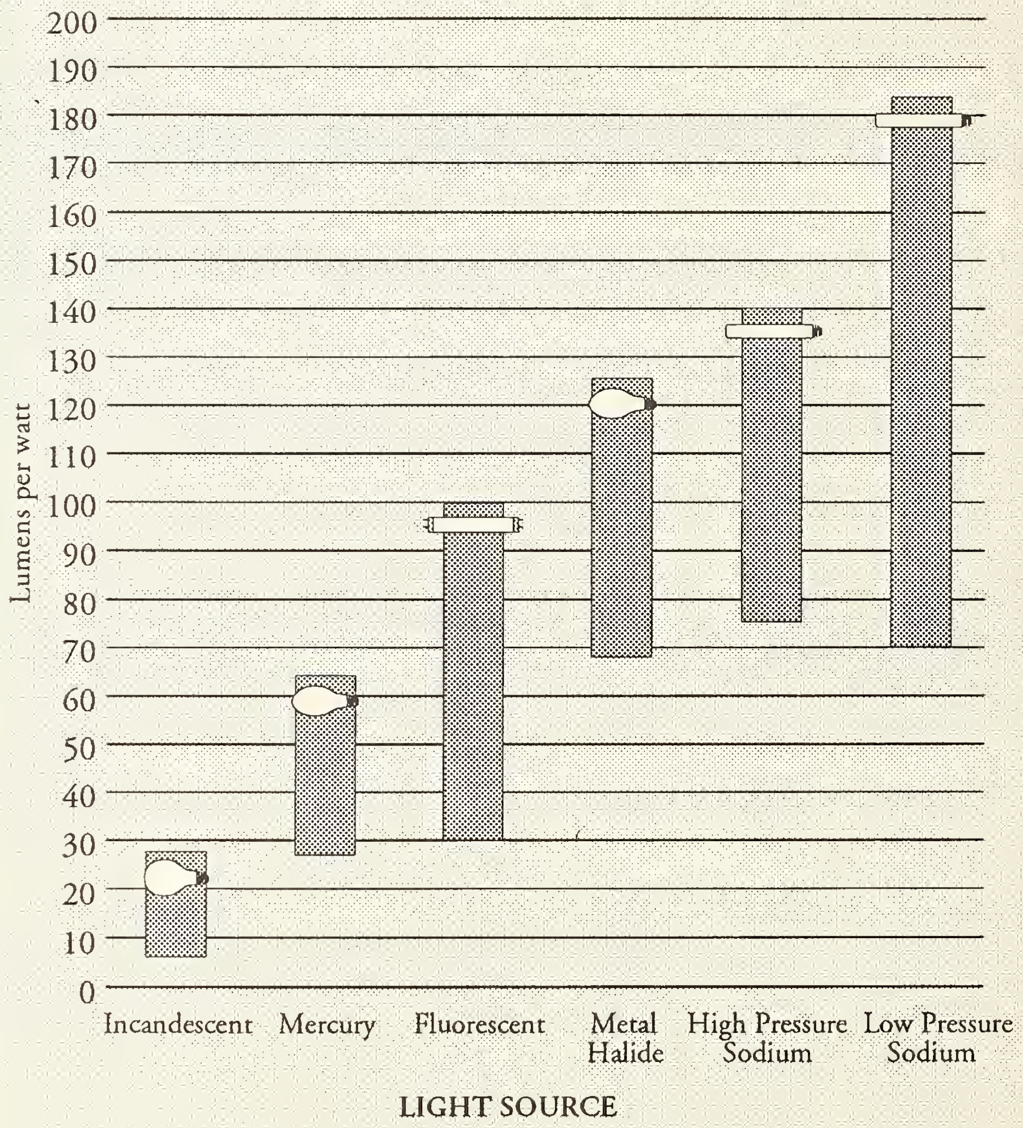
### Lighting

Matching lighting output to requirements, locating light sources properly, and choosing efficient fixtures will conserve on the electricity bill. Work areas require more intense light than relaxation areas. Individual table or floor lamps may work better than a single ceiling source in bedrooms. Fluorescent light sources will give more output for less wattage than incandescent lighting and should be used in task areas such as the kitchen, laundry, or workshop.

High-pressure sodium lights should be considered for exterior security, roadway lighting, and recreational lighting.

## COMPARING TYPES OF LIGHT SOURCES

Light sources have differing efficiencies. The following figure shows how the number of lumens per energy used (watt) varies with the type of bulb. Incandescent bulbs are the most expensive in energy cost, emitting only 7 to 28 lumens per watt, and have a short life span. Low pressure sodium lights are the least expensive with an average output of 70 to 183 lumens per watt.




*Comparing Energy Efficiency of Light Sources*
*Source: Energy Resource Center, Tualatin, Oregon*

# Appendix

## Btu (British thermal unit)

Heat requirements of houses and the amount of heat derived from various heating fuels and systems commonly are expressed in Btu. A Btu represents the amount of heat needed to raise the temperature of 1 pound of water by 1 degree F. One Btu is about equal to the heat given off by one kitchen match.

*Btu Content of Energy Sources*

| Energy Source | Amount | Btu |
|---|---|---|
| electricity | 1 kilowatt-hour | 3,413 |
| electricity | 1-ton heat pump | 12,000 per hour at 45 degrees F outdoor air |
| natural gas | 1 cubic foot | 1,000 to 2,000 |
| natural gas | 1 therm | 100,000 to 120,000 |
| | 1 MCF | 1,000,000 to 1,200,000 |
| propane gas | 1 cubic foot | 2,516 |
| propane gas | 1 therm | 92,000 |
| No. 2 fuel oil | 1 gallon | 138,000 |
| gasoline | 8.13 gallons | 1,000,000 |

## Degree days

Degree days are used to estimate average heating requirements. One degree day accrues for every degree the average outside temperature is below 65 degrees F for a 24-hour period. Days with average temperatures above 65 degrees are not counted. For example, if the outside air temperature is an average 30 degrees F over a 24-hour period, then 35 degree days accrue (65-30=35). Thus, the more degree days, the colder the climate.

The average number of degree days can be used in conjunction with heat flow calculations to estimate the number of Btu required to heat a given structure in a given locality.

*Total Average Heating Degree Days*
*for Various Montana Locations*
*(base 65 degrees F)*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Augusta | 8000 | Cut Bank | 9033 | Hebgen Dam | 10574 | Roundup | 7015 |
| Babb | 9327 | Darby | 7361 | Helena | 8190 | Saint Ignatius | 7197 |
| Ballantine | 7202 | Dillon | 8354 | Heron | 7738 | Savage | 8473 |
| Belgrade | 8686 | Dunkirk | 8998 | Holter Dam | 6802 | Scobey | 9069 |
| Big Sandy | 8219 | East Anaconda | 8414 | Huntley | 7535 | Seeley Lake | 8773 |
| Big Timber | 6766 | Ekalaka | 8163 | Jordan | 8099 | Simpson | 9263 |
| Bigfork | 7211 | Ennis | 8020 | Kalispell | 7842 | Stevensville | 7668 |
| Billings | 7265 | Fairfield | 7835 | Lewistown | 8586 | Summit | 10628 |
| Boulder | 8572 | Flatwillow | 7678 | Libby | 7443 | Superior | 7203 |
| Bozeman | 8165 | Fort Assinniboine | 8678 | Lima | 9567 | Thompson Falls | 6684 |
| Bridger | 7036 | Fort Benton | 7657 | Livingston | 7593 | Townsend | 8227 |
| Broadus | 7871 | Fort Peck | 8427 | Medicine Lake | 9225 | Trident | 7393 |
| Browning | 9056 | Fortine | 8424 | Melstone | 7325 | Trout Creek | 7648 |
| Busby | 8037 | Gibson Dam | 8591 | Mildred | 8073 | Troy | 8129 |
| Butte | 9719 | Glasgow | 8969 | Miles City | 7889 | Turner | 9199 |
| Cascade | 7324 | Glendive | 7774 | Missoula | 7931 | Valier | 8380 |
| Circle | 8652 | Grass Range | 7765 | Moccasin | 8398 | Vida | 8672 |
| Chinook | 8465 | Great Falls | 7652 | Mystic Lake | 8601 | Virginia City | 8489 |
| Choteau | 7954 | Hamilton | 7187 | Norris | 6970 | West Glacier | 8465 |
| Colstrip | 7441 | Hardin | 7530 | Philipsburg | 8856 | West Yellowstone | 10986 |
| Columbus | 7331 | Harlem | 8729 | Plevna | 8543 | Westby | 9573 |
| Conrad | 8142 | Harlowton | 8117 | Poplar | 8823 | White Sulphur Spgs | 8792 |
| Cooke City | 11316 | Haugan | 8152 | Rapelje | 7727 | Wibaux | 8892 |
| Crow Agency | 7436 | Havre | 8687 | Red Lodge | 8501 | Winifred | 8288 |
| Culbertson | 9163 | Haxby | 8337 | Rock Springs | 8401 | Wisdom | 10824 |
| | | | | | | Wyola | 7468 |

*Source: Climatological Data, Volume 81, Not. 7, National Oceanic and Atmospheric Administration, Asheville, NC*

## Heat Flow Calculation

The amount of heat a house loses can be estimated from the R-values and U-values of its components. R-values and U-values measure the same property—heat transfer capacity—but in opposite terms, resistance and conductance.

R-value measures a material's resistance to heat conductance. The R-value is the number of hours it takes 1 Btu to travel through a material with 1 degree temperature difference between the two sides. For example, it would take 19 hours for 1 Btu to go through an R-19 piece of insulation with 1 degree temperature difference between sides. The greater the R-value, the slower the heat flow.

U-values, by contrast, measure a material's ability to conduct heat. The U-value is the number of Btu, or the amount of heat, that flows through a square foot of material in an hour with a 1 degree temperature difference between the two sides. For example, 1 square foot of double glazing with low-E film that has a rated U-value of 0.31 would allow about 1/3 of a Btu to flow through in 1 hour

when the temperature difference between its two sides is 1 degree F. The lower the U-value, the lower the heat flow.

Each can be determined by taking the reciprocal of the other. For example, an R-value of 19 equals an approximate U-value of 0.053 (1 divided by 19). A U-value of 0.31 equals an approximate R-value of 3.2 (1 divided by 0.31).

Many builders and utility companies have computer programs that calculate heat loss for a proposed house design. The prospective house buyer furnishes house dimensions, window and door square footage, and R-values of walls, ceiling, foundation, windows and doors.

## House Heating Requirements

A rough estimate of the amount of fuel a house will use for space heat can be obtained by correlating heat flow with degree days. Say that heat flow calculations predict a house will lose 319 Btu per hour for each degree the outside temperature is less than 65 degrees F. Over a 24-hour period, the estimated heat loss would be 7,656 Btu (319 Btu/hour x 24 hours) for a 1-degree difference. If the house is in Kalispell, the estimated annual Btu loss will be 7,656 Btu/degree day x 7,842 degree days for a total of 60,038,352 Btu.

However, the predicted heat loss will be offset by heat generated by people, appliances, and other internal sources, and from the sun. Internal gains for a typical house average 3,000 Btu per hour, 65 percent of which will offset space heat required Solar gain contributes about 15 percent of the space heat required. For the Kalispell example, the calculations are:

Offset for internal gains:
3,000 Btu/hour x 24 hours/day x 365 days x 65% = 17,082,000 Btu annually

Offset for solar gain:
60,038,352 x 15% = 9,005,753 Btu annually

Total offset:
17,082,000 + 9,005,753 = 26,087,753 Btu annually

Net heat requirement:
60,038,352 - 26,087,753 Btu = 33,950,599 Btu annually

### Calculating annual fuel use

To calculate estimated annual fuel use, divide the net heat requirement by the number of Btu in the fuel source unit, add in the loss due to the inefficiency of the heat delivery system, and multiply fuel units required by the fuel price. The table on page 45 shows the Btu content of the major fuels.

### Natural gas heat

For the example above heated with natural gas, the net fuel requirement would be:

33,950,599 Btu/1,000,000 Btu per MCF = 33.951 MCF

If the heating system is a furnace of 83 percent efficiency, add 17 percent:

33.951 MCF x 1.17 = 39.723 MCF

Multiply the fuel units required by the fuel price. If natural gas is $3.50 per MCF, the estimated annual heating bill would be:

39.723 MCF x $3.50/MCF = $139

### Electric heat

For the example above heated with electricity, the net energy requirement would be:

33,950,599 Btu/3,413 Btu per kWh = 9,947 kWh

If the heating system is electric baseboard, it is 100 percent efficient:

9,947 x 1.00 = 9,947 kWh

Multiply the fuel units required by the fuel price. If electricity is 5 6/10 cent per kWh, the estimated annual heating bill would be:

9,947 kWh x $0.056 per kWh = $557

## Sizing the heating system

The heating system will be sized to keep a house warm based on the difference between 65 degrees and the average coldest temperature. If that temperature is -20 degrees, the difference will be 85 (65 degrees minus -20 degrees = 85). If the house has a heat loss of 319 Btu per hour for each degree, the heating plant must be capable of delivering at least 319 Btu per degree difference x 85 degrees or 27,115 Btu per hour to keep the house warm on the average coldest day. At this point, the efficiency of the heating system is considered. For this example, consider an 83 percent efficient gas furnace or a 100 percent efficient electric baseboard:

27,115 Btu x 1.17 = 31,725 Btu gas furnace

27,115 Btu x 1.00 = 27,115 Btu electric baseboard

Because some days will be colder than the average, heating systems are sized 50 percent larger than the bare minimum. Therefore, a gas heating system for this hypothetical house should deliver at least 31,725 x 1.50 or 47,588 Btu. Because gas furnaces come in standard Btu sizes, the size above the required Btu will be used, in this case probably a 50,000 Btu furnace.

For this hypothetical house, an electric baseboard system should deliver a minimum of 27,115 x 1.5, or 40,673 Btu. To translate the baseboard system into watts and baseboard footage length:

40,673 Btu/3,413 = 11.91 kWh

1,000 Watts per kWh x 11.91 kWh = 11,910 watts

11,910 Watts/250 Watts per foot = 48 feet of baseboard required throughout the house

NOTE: **Because the highest heat demand will be at night, internal and solar gains are not considered.**

# More Information

## Builder Training Seminars

The prospective house buyer is encouraged to attend builder training seminars sponsored by local utilities and the Department of Natural Resources and Conservation. Dates, times, and locations of the seminars can be obtained by calling DNRC at 444-6697.

## Houseplans

Several companies are now specializing in energy-efficient house plans, and their publications may be found in magazine stores. An architect or knowledgeable builder can modify basic house plans to include energy-efficient features.

## Publications

The following publications provide greater construction detail and we suggest prospective home buyers either borrow them from a library or buy their own copies.

Alberta Agriculture, Home and Community Design Branch, and Alberta Energy, Energy Conservation Branch. ***Low Energy Home Designs.*** Edmonton, Alberta: Alberta Agriculture. 1987.

Alberta Agriculture
Print Media Branch
7000 - 113 Street
Edmonton, Alberta
T6H 5T6

Canadian Home Builders' Association. ***R-2000 Builders' Manual.*** Ottawa, Ont: CHBA. 1987

Canadian Home Builders' Association
Suite 701
331 Cooper Street
Ottawa, Ontario
K2P 0G5

Lencheck, Thomas, Chris Mattock and John Raabe. ***Superinsulated Design and Construction.*** New York: Van Nostrand Reinhold Company. 1987

Lischkoff, James K. and Joseph Stiburek. *The Airtight House: Using the Airtight Drywall Approach.* Ames, IA: Iowa State University Research Foundation, Inc. (no date)
Engineering Extension Service
Iowa State University,
Ames, IA 50011

National Forest Products Association and The Society of the Plastics Industry, Inc. *Guidelines for Installing and Finishing Wood and Hardboard Sidings Over Rigid Foam Sheathing.* Recommendations of Joint Industry Committee on Wood Siding and Foam Sheathing. October 1983.

Scott, Linda and Michael, and Richard Hand. Superinsulation Design and Construction. Anoka, MN: *Superinsulation Ltd. and Hand Construction.* 1984
Superinsulation Ltd. and Hand Construction
13770 Underclift Street N.W.
Anoka, MN 55303

Underground Space Center, University of Minnesota. *Building Foundation Design Handbook.* Oak Ridge, TN: Oak Ridge National Laboratory, 1988
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

University of Illinois. A catalog describes special publications prepared by the University, which cover a wide range of construction and design practices.
Small Homes Council-Building Research Council
University of Illinois
One East St. Mary's Road
Champaign, IL 61820

## Periodicals

The following are some of the trade magazines or newspapers specializing in energy-efficient building techniques.

*Custom Builder.* 7650 Old Dixie Highway, Box 2, Winter Beach, FL 32971. 207-846-0970.

*Energy Design Update.* Cutter Information Group, 1100 Massachusetts Avenue, Arlington, MA 02174. 617-648-8700.

*Fine Homebuilding.* The Taunton Press, PO Box 355, Newtown, CT 96470. 800-243-7252.

*New England Builder: The Journal of Light Construction.* Builderburg Group, Inc., PO Box 278, Montpelier, VT 95602. 800-345-8112.

*Practical Homeowner.* P.O. Box 58977, Boulder, CO 80322-8977. 800-525-0643.

*Professional Builder.* Cahners Publishing Company, 270 St. Paul St., Denver, CO 80206-5191. 303-388-4511.

## Videotapes

Video tapes are available that describe energy-efficient construction techniques. The video titles, viewing time in minutes, and issue date are listed below. The films may be borrowed from the Montana State Film Library, local offices of Montana Power Company, or from the rural electric cooperatives listed. The Film Library charges $2 to cover postage and handling.

Advanced Framing 18:15 (1986)
Batt Insulation: Walls and Floors 15:50 (1986)
Advanced Drywall 40:00 (1986)
Rigid Insulation for Interior Side of Above-grade Walls 12:30 (1987)
Rigid Insulation for Exterior Side of Above-grade Wall 20:00 (1987)
Qualifying Your Home for the Super Good Cents Program 23:00 (1987)
How to Calculate Design Heat Load 45:00 (1987)
Introduction to Residential Mechanical Ventilation 25:00 (1987)
Energy-efficient Windows 12:00 (1987)
How to Insulate Attics 15:00 (1987)
How to Insulate Cathedral Ceilings 10:00 (1987)
Double Wall Construction 15:30 (1987)
How to Insulate Concrete Slabs 16:45 (1988)
Super Good Cents Homes 6:30 (1988)
Super Good Cents Manufactured Homes 5:00 (1988)
Super Good Cents: A Program for Builders 8:30 (1988)
Zonal Electric Heat 17:30 (1988)
Controlling Indoor Moisture 16:25 (1988)
Building Homes for Comfort and Savings 27:00 (1988)
Tracking and Inspecting Super Good Cents Home Construction 24:30 (1989)
Air-to-air Heat Exchanger Systems: Marketing, Design and Installation
Part 1: 43:00; Part 2: 23:00 (1989)
A Marketing Framework for Super Good Cents 30:19 (1989)
Radon Control in New Home Construction 20:24 (1989)
Window Design Decisions 19:30 (1989)
How to Insulate Basements 16:15 (1989)
Minimizing Heating and Cooling Duct Losses 14:30 (1989)
Installing Non-heat Recovery Ventilation Systems 42:15 (1989)
Sealing Air Leaks During Construction 18:30 (1989)

Montana State Film Library
106 West Broadway
Butte, MT 59701
723-8262, ext. 377

Rural Electric Cooperatives
Flathead Electric Cooperative
Glacier Electric Cooperative
Lincoln Electric Cooperative
Mission Valley Power
Missoula Electric Cooperative
Ravalli Electric Cooperative
Vigilante Electric Cooperative

## DNRC Information

Several free publications from the Department of Natural Resources and Conservation discuss energy-efficient houses and different types of heating systems. Call 444-6697 or write Energy Division, DNRC, Capitol Station, Helena, MT 59620 to order these publications.

*Warm Places—A sampling of energy-efficient Montana homes*
*Super Good Cents Home Buyer's Guide*
*Sunspaces—A Montana Guide*
*Electric Heating Options*
*Gas Furnaces and Appliances—Sorting Through the Options*
*Wood Heat*
*Ventilating Your Energy-efficient Home*
*A Citizen's Guide to Radon—What It Is and What To Do About It*
*Radon Reduction Methods—A Homeowner's Guide*
*The Montana Energy Book—Proven Ways to Save Money In and Around Your Home*

## Other Sources of Free Information

City or county libraries

County Extension Services

Local utilities

National Appropriate Technology Assistance Service
P.O. Box 25254
Butte, MT 59702-2525
1-800-428-1718

Energy Division
1520 East Sixth
Helena, MT 59620-2301

Montana Department of Natural
Resources and Conservation